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J. F. KELLY, Editor

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INSPECTION TRIP

Saturday, June 2nd, 1928

Tentative

E. W. BLISS CO.

SALEM, OHIO

EXHIBIT

Cluster Type Rolling Mills

All Roller Bearing Equipped

DEMONSTRATION

Cold Rolling Sheet Steel, Copper, Brass

Mill Electrically Driven

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Reduction Gears, Rolls, Roller Bearings, Magnetic Clutch, Oiling System, Couplings, Tension Rolls, Etc.

COMPLETE DETAILS WILL BE ANNOUNCED LATER

EDITORIAL

NATIONAL WELDING CONFERENCE AUSPICES CLEVELAND DISTRICT SECTION ASSOCIATION OF IRON AND STEEL ELECTRICAL ENGINEERS

ABOUT 250 members and guests attended the National Welding Conference of the A. I. & S. E. E. held Friday, April 20, 1928, at Cleveland, Ohio, under the auspices of the National Welding Committee. This Committee is composed of Messrs. A. G. Place, Electrical Engineer, Youngstown Sheet & Tube Company; S. S. Wales, Chief Electrical Engineer, Carnegie Steel Company; R. S. Shoemaker, Superintendent of Maintenance, American Rolling Mills; R. M. Hussey, Electrical Engineer, Jones & Laughlin Steel Company, and A. J. Standing, Electrical Engineer, Bethlehem Steel Company.

The members and guests representing practically the steel industry, met at the Hotel Statler at 10 A. M. to attend the various committee meetings being held at that place.

The National Board of Directors also met in executive session. At 11:45, the members and guests participated in an elaborate luncheon and at 12:30 they were driven to the Cleveland Crane & Engineering Company's Plant, at Wickliffe, Ohio, where a complete demonstration of Electric Arc Welding was the feature.

A 10-ton crane, completely arc welded, created an enormous amount of interest. Many other examples of arc welding were exhibited. The shops of the Cleveland Crane & Engineering Company were also thrown open for the inspection of the visitors and many ingenuous devices for building cranes were carefully inspected.

At 3 P. M. the members and guests were transferred to the Lincoln Electric Company Plant where guides piloted groups of thirty through this plant. All types of electric welding were exemplified, starting with the motor frame and running to the complete motor.

Arc welding is practiced to the fullest extent at this plant. The Lincoln Electric Company was congratulated by the many visitors on the advances they had made in the art of welding.

At 6 P. M., all the members and guests assembled at the Main Ball Room of the Statler Hotel, where a very sumptuous dinner was served, everyone being the guests of the Lincoln Electric Company and the Cleveland Crane & Engineering Company.

After the dinner, Mr. A. G. Place introduced Mr. A. J. Standing, President of the A. I. & S. E. E., who thanked both companies for adding materially to our store of welding knowledge. Mr. Standing Covered the following points: Arc welding from the maintenance standpoint, the relation between the tonnage of castings and the possible tonnage of structural material which would replace those castings, were it possible to apply arc welding, the application of various types of welding, the procedure in welding must be careful in order to avoid chance of failure, the selection of welding operators and structural welding.

Mr. John Lincoln, President, Lincoln Electric Company, presented a very interesting paper on the subject of "Arc Welding is Selling Steel."

Mr. Lincoln's paper covered the following major points:

Early History of Arc Welding.

Arc Welding in Repairs and Maintenance.

Arc Welding as a Means for the Extensive Use of Roll Shapes in Place of Castings.

Machinery Manufactured by Lincoln Electric Company Changed from the Usual Cast Construction to the Welded Steel Construction.

Experiences.

Methods and Data Compiled During the Development of Welded Steel Construction.

Savings Effected in the Welded Type of Construction.

In addition to the above, Mr. Lincoln made comparisons of rolled steel and cast iron construction, relative inventory account carrying structural steel and cast iron, relation of scrap to welded steel and cast construction, special designs, elimination of pattern costs, drawing cheaper, deliveries advanced with the use of welded construction, freight and handling costs.

He also discussed welded construction versus riveted construction, and gave the reasons why progress in welded construction have not advanced more rapidly. In closing his talk, he cited the many opportunities for engineering talent in welding.

Mr. Edwin L. Upp, Electrical Engineer, Gary Tube Company, expressed the opinion that electric welding was making rapid advances in tubular practices.

Mr. W. G. Wehr, Manager, Cleveland Crane & Engineering Company, expressed the idea that while the personal element had a great deal to do with successful welding, they never had any trouble securing or educating the necessary operators and that it had never been any more trouble to secure welders than machinists or electricians.

Mr. A. G. Place, Electrical Engineer, Youngstown Sheet & Tube Company, brought up the question of the relation of some of the variables that enter into welding such as the effect of variation on current, the diameter of the welding wire, the speed of welding, how it might be effected by the rod diameters, the account of current used, etc.

Mr. J. C. Cumberland, General Electric Company, Schenectady, N. Y., spoke on the personal element in welding, claiming too much stress was being laid upon this factor. Proper equipment, proper material to work with, correct supervision were the most important factors in arc welding.

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FUEL SAVINGS CONFERENCE

COMBUSTION ENGINEERING DIVISION

of the

A. I. & S. E. E.

EDGAR THOMSON PLANT, CARNEGIE STEEL COMPANY, BRADDOCK, PA.

INSPECTION TRIP

Edgar Thomson Plant, Carnegie Steel Co.

MARCH 29, 1928

"HISTORY OF THE EDGAR THOMSON PLANT," by L. C. Edgar, Chief Engr., Edgar Thomson Works, Carnegie Steel Co., Braddock, Pa.

TECHNICAL SESSION

"DRY QUENCHING OF COKE," by Walter Sennhauser, Chief Engr., Dry Quenching Equipment Corp., New York, N. Y.

"POWDERED COAL AS APPLIED TO INDUSTRIAL FURNACES," by W. A. Shoudy, Associate Professor, Mechanical Engineering, Columbia University, New York, N. Y.

A. J. Standing: I had the opportunity before Mr. Hartsuff left of expressing my personal appreciation and in behalf of the Association of the courtesies extended to us, and I repeat that expression of appreciation to Mr. Edgar.

I want to say a word about the Combustion Section of the Association of Iron & Steel Electrical Engineers. In 1919 or 1920 we began to realize the combustion engineers had reached a place where they were becoming prominent and had to have an affiliation and if they did not come with us they would go somewhere else. So in 1921 we had a Fuel Saving Conference in Chicago under Mr. F. E. Leahy as chairman. In 1922 our Combustion Committee was formed under the leadreship of Mr. Leahy, and that committee has continued to function since that time. In 1927 when making a revision in the constitution we definitely recognized a Combustion Engineering Section with representation on our board of directors. So the Combustion Engineering Section has a very definite identity and has a place in all activities of the Association. Its success is due entirely to the caliber of its leaders and to the activities of its members. When you consider that since 1921 and 1922 we have had seventy-five major papers presented before the Association on combustion, and this year including the combustion papers today, there will be ten additional papers presented, you can realize the section has been doing some work. They have been developing new fields on account of economies which plants are being forced into and their investigation has had its bearing on our success as an Association.

They tell a story of a combustion engineer who went to a Southern town. The porter asked where are your sample cases? The combustion engineer said, I have no sample cases, I sell brains. The porter remarked, you are the first man who has come down here who has no sample of what he sells. While I see no sample of what he sells. While I see no sample cases in evidence, I know the combustion engineer is certainly long on brains, and it would seem that the men of the electrical end of the Association will have to watch their step if they are going to keep up with you. As an Association we welcome your work. It adds to our prestige and there is no doubt with combustion work and electrical work so inter-locked but what we can gain a great deal from each other. I want to extend an invitation to all of you men not now members to join with us in this work. From the activities and work carried on there are many opportunities where you can gain and where you can give, and by the co-operation of the electrical men with the combustion men, we can advance ourselves and advance the steel industry which we serve. At this time it gives me a great deal of pleasure to introduce to you Mr. M. J. Conway, Combustion Engineer, Lukens Steel Company, Coatesville, Pa., who is also the Chairman of the Combustion Engineering Division of the Association of Iron & Steel Electrical Engineers. Mr. Conway.

President, A. I. & S. E. E.

Martin J. Conway: We are very fortunate in that we have been invited to visit the Edgar Thomson Plant today. It is one of the largest steel plants in the United States as well as being one of the pioneer plants, which speaks well for its management and the progress they have made in continuing to keep it to the forefront in the steel industry.

We are grateful to the Carnegie Steel Company, Mr. Edgar and Mr. Hartsuff for their generous hospitality and offer our congratulations for the appearance of their plant. It is clean, its safety record enviable, it is electrically and mechanically healthy and it has many economic features which are deeply interesting to us as combustion engineers. It is pleasurable and instructive to visit plants of this caliber and our time is well invested if we can carry away with us only a small part of the picture which has been our good fortune to have had presented to us today.

That the members and guests present at this meeting may become more intimately acquainted with the management of the plant who have been so hospitable to us today, I want to introduce to you Mr. L. C. Edgar, Chief Engineer of the Edgar Thomson Steel plant.

He has been responsibly closely connected with the improvements of the plant for a number of years.

Mr. Edgar is going to tell us something about the history of the Edgar Thomson Plant.

History of the Edgar Thomson Works of the Carnegie Steel Company*

L. C. EDGAR†

IN behalf of the management of Edgar Thomson Works, and particularly, Mr. Hartsuff, our General Superintendent, I wish to say how much we appreciate having you gentlemen here today. The Association of Iron & Steel Electrical Engineers has always stood in the forefront of the engineering societies. They have been progressive in making friends and the work they have done electrically and otherwise has accomplished a great deal for the engineers that have been trying to build up their plants and improve their operations, and it speaks well for the progress of the Association of Iron & Steel Electrical Engineers that they have a section called the Combustion Engineering Section.

The combustion engineer is an outgrowth of the economic era we are working in today. When we care little or nothing of the waste and abuse of the fuel we have and abuse of our natural resources, the combustion engineer has no part; but when we do care for the conservation of our resources and conserve the use of coal and other fuels, then the combustion engineer plays a large part, and it speaks well of this Association that they have a combustion section and is one of the earmarks of an aggressive Society. We at Edgar Thomson, therefore, felt highly flattered when they asked to have representatives of the Combustion Engineering section to look through our plant and see what Edgar Thomson was doing. We hope you will not go away disappointed in the things you have seen, because we feel there is much more to do than has been accomplished and we are looking forward rather to the things we hope to do than the things that have gone before.

We appreciate having you here and welcome you with all our hearts, and we are glad that you spent a few hours in looking us over and that you cared to have your meeting here, and we hope in the future, as times go by and we have improvements, that you will come again, and assure you that you will be welcome.

Braddock is historic ground, being the scene of General Braddock's defeat, and the path of Braddock's army was right across the field on which Edgar Thomson Works is now located. It is fitting, therefore, that we have a few things said about the Edgar Thomson plant. I have asked Mr. Hugh P. Meese, the secretary to the general superintendent and the historian of the works, to write me a little summary of the things that could be said about the history of Edgar Thomson, and if you will bear with me, I will read at least a portion of what he has written.

Except for the period of the World War, the decade following the Civil War marked the greatest development our country has ever had along commercial lines, and a variety of causes focalized that prosperity on Western Pennsylvania, which was at the time the center of the coal and iron industry of the United States. During the Civil War iron had risen as high as $73.60 a ton. Shortly thereafter the railroad mileage in the country had doubled, and at this time also came the development of the Connellsville coke region, the introduction in America of the Bessemer steel process, and a wild demand for rails that sent the price of iron rails to as high as $100 a ton, and of steel rails, up to $175 a ton.

Andrew Carnegie, in 1872, viewed the European process of making rails, and on returning to Pittsburgh, decided to have a Bessemer rail plant himself. He thereupon bought an option on 107 acres of land at Braddock along the Monongahela river and late in 1872 work was commenced on a wharf to handle the river freight. The deal was completed January 1, 1873, when William Coleman, with whom Carnegie was allied, made the formal purchase in behalf of himself and Messrs. Andrew Kloman, Henry Phipps, David McCandless, Wm. P. Shinn, John Scott, David A. Stewart, and Thomas and Andrew Carnegie, the capital stock of the original firm being $700,000, with the name of Carnegie, McCandless & Co., and with an eye to future business they named the plant after J. Edgar Thomson, then President of the Pennsylvania Railroad. The plant was designed by A. L. Holley, and Phineas Barnes, who built the Joliet plant, superintended the erection.

Upon the completion of the plant, Captain William R. Jones, of the Cambria Iron Works, was made General Superintendent, and the Converting Mill of the new plant made its first blow August 26, 1875, the first rail being rolled September 1, 1875.

The original plant had two 5-ton converters, with rated capacity of 225 tons daily, blooming mill, and rail mill, which was a three high, 23-inch, hook and tong mill, with 12 to 14 rail passes in all, four straightening presses and four drill presses.

On October 12, 1874, due to financial troubles of various members, the original firm dissolved into the Edgar Thomson Steel Co., Limited, and the plant was early forced to high efficiency by the falling market for rails, which dropped from $120 a ton in 1873 to $42 a ton in 1878. Jones, however, was a mechanical genius who managed to make the business pay, by constant improvement and invention.

The new plant needed blast furnaces, and a small furnace at Escanaba was transported to Edgar Thomson and became our "A" Furnace, which began operation in 1880, producing 56 tons daily. A second furnace, the "B" followed that same year, as did the "C", these latter two being built to produce 5,500 tons monthly. With this increase in equipment, the firm began making money, and in 1880 their annual profits amounted to $1,625,000.

By 1887 four more blast furnaces, the D, E, F and G, had been added to the plant, and in 1888, Jones' greatest invention, the Jones Mixer, with 125 tons capacity, was placed in operation, the patent

*Presented before Combustion Engineering Section, March 29, 1928.

†Chief Engineer, E. T. Works, Carnegie Steel Co., Braddock, Pa.

for which the Steel Corporation was obliged to defend in 1905. Also in this year the second rail mill was added, consisting of two three-high and one two-high 24" train of rolls, each independently driven. Seventy Boilers were required for this plant ,and the converters were increased to 10-ton capacity. In 1889 the annual output of the plant had risen to 277,401 tons of rails. Capt. Jones died as a result of a blast furnace accident September 28, 1889, leaving a remarkable record of affection among all his men.

Capt. Jones was succeeded by Charles M. Schwab October 1, 1889, who had been developed by the Captain by supervising work not only here but at Homestead, which plant had been under Edgar Thomson management up to October 1, 1892. Under this famous steel master, the Blooming Mill was changed to a three-high 40" mill. The electric light plant at that time contained three Brush 65-light dynamos, running about 175 arc lamps, and securing power from three 11x22" Buckeye engines. During 1890 the H and I Furnaces were added, and during Schwab's administration the blast furnaces averaged 55,000 tons of iron monthly. Best record for a single blast furnace was 457 tons in 24 hours, and best daily rail record, 1,417 tons.

The labor trouble at Homestead eventually caused the transfer of the popular C. M. Schwab to that plant, where he went October 1, 1892, and the management of Edgar Thomson was placed in the hands of James Gayley, then Supt. of Furnaces. He invented the bronze cooling plate for blast furnace walls, the auxiliary casting stand for Bessemer steel plants, and was the first to use the compound condensing blowing engine with the blast furnace. In 1893 he built our No. 1 Foundry, the No. 2 in 1894, and No. 3 in 1894. He was transferred to City Office March 1, 1895, and succeeded by Thomas Morrison, then superintendent of Duquesne Works, who in 1897 built a new power house, installed double furnace bells, and changed furnace skips to electric drive. In 1898 he installed the pig machine at furnaces, which was a revolutionary innovation. He also specialized on steam economy and replaced many old boiler houses and in 1897 installed the first Weiss central condensing plant in this country. In 1899 he erected the present Converting Mill building, with four 15-ton converters. He inaugurated the weekly meeting of department heads October 18, 1899. His administration was brilliant and efficient throughout, but being a man of wealth his personal affairs required ever more and more of his attention, so that he finally retired June 1, 1903, being succeeded by his assistant, Charles E. Dinkey.

Under Mr. Dinkey's administration the plant had a great expansion and development. In 1905 the first engine to run on blast furnace gas in this country was installed at Edgar Thomson, a horizontal tandem Westinghouse engine of the four cycle constant mixture type. No. 3 Mill, for light rails, was put in operation in July, 1905, the first electrical mill in America. In 1908, as a step toward improved quality, the five pass roughing rolls in No. 1 Mill were changed to seven pass with excellent results regarding quality, but not so good as to tonnage. In 1908 the 15-ton iron ladles at the furnaces were replaced by ten 35-ton ladles and in 1909 seven electrically operated ladle dumpers were started at pig machine.

The demand for O. H. rails had been increasing and our Open Hearth Department was accordingly built in 1912, the original 14 furnaces being completed in 1914, with rated capacity of 90 to 100 tons per heat, and the first heat produced August 16, 1913. Our Splice Bar shop was moved here from Duquesne in 1910, which year also saw the erection of the flue dust briquetting plant, and it is our plant which must be credited for the development of the flue dust briquetting process and perfection of the high carbon splice bar. Our hospital was built in 1912, and electrical ingot strippers were put in operation in 1913.

The present No. 2 Mill was erected in 1915, a 32-inch four stand mill with 79 motors, as originally planned. In 1916 the present office building was erected, the club house having been put up in 1912.

The most radical improvement in standard blast furnace lines was made under this administration with the blowing in of Furnace "I" in 1907. For that furnace the former 15-foot hearth was widened to 17 feet and the lower bosh angle widened to over 78 degrees, this pronounced departure being put in by Mr. Dinkey in the face of protest by many furnace experts. The new lines, however, immediately proved successful.

This outline, however, would not be complete without some discussion of the work done by the present administration. Most of you are familiar with the work done under Mr. Hartsuff's administration. Nevertheless, I feel that a few remarks in this regard are apropos:

Mr. Hartsuff has always been interested in the conservation of fuels, and this is borne out by the work which has been accomplished under his direction. The installation of the new Stirling Boiler House which you have seen this morning and the Turbo Blower installation, both of which are not only designed for the purpose of saving of fuel but effect material labor savings, were made possible by his approval and energetic backing.

He has always taken an interest in electric power generation and has backed up Appropriation Requests and secured for us Appropriations for the 15,000 KW Generator Set, Improvements to our Transmission System, and many other improvements in the electrical field.

He has also made possible the installation of additional improvements and rebuilding of our Open Hearth Plant with the installation of two additional furnaces to the original fourteen and the rebuilding of five of our old furnaces and is today energetically advocating the improvement of the remainder of the furnaces.

In addition to these improvements which are particularly related to the economies in which the combustion section are interested, there have been carried on during his administration many other improvements in Mills and Blast Furnaces which have resulted in substantial savings. In the handling of material and transportation field, he has done much to improve our conditions, lowering our cost of yard switching and hauling, and has obtained for us an Appropriation for the Installation and Electrification of Hot Metal Elevated which has resulted in substantial economies.

In plant welfare, he has secured for the District an Athletic Field which is second only to Forbes

Field, and installed numerous facilities and Sanitary Drinking Water for the plant, all for the interest and welfare of employees.

In addition to the above, his systematic and well directed efforts in labor conservation have done much to reduce the cost of our finished products; this being done without any semblance of driving or expecting from any man more than could be considered a fair day's work; in fact, labor conditions have been bettered and the quality of product under his administration has improved as well as cost lowered, and we look on him as one of the greatest of those who have exercised the management of Edgar Thomson Works.

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*Dry Quenching of Coke**

By WALTER SENNHAUSER†

ON the basis that 'brevity is the soul of wit,' this will be a witty engineering paper. The story of Dry Quenching is so simple, so logical, and by now so well established that it seems to me only necessary to recite the principal facts in connection with the twelve plants throughout the World that are now in operation, to fire the imagination of the most conservative engineer to one of the greatest possibilities for thermal conservation that has been presented,—and yet one so immediately handy as to make possible its early accomplishment.

In quenching hot coke with water, the sensible heat of the coke is wasted. In 1926 about 44,000,000 tons of coke were produced in the United States. Assuming a temperature of the glowing coke of 1800° F., and a specific heat of 36, the fuel wasted in 1926 was the equivalent of 2,250,000 tons of coke, or more than 5% of the total coke production.

Cold water poured on glowing coke cracks the pieces forming breeze. The draining water washes away part of this breeze, and that recovered is generally too wet for use as fuel. This loss amounts to about .5 to 1% of the coke quenched.

There is one particular menace to wet quenching which has caused embarrassment in many plants located in, or adjacent to, cities; that is, the carrying of fine particles of breeze high into the atmosphere with the vapors from the wet quenching plants. This, in turn, being scattered widely over the community. Naturally, Dry Quenching does away with all this.

The usual winter troubles experienced with wet quenching are, of course, eliminated with Dry Quenching.

In the Sulzer System of Dry Quenching, the cooling is accomplished by circulating the inert gases of combustion in a closed cycle, first through the glowing coke mass, where the gases extract the sensible heat from the glowing coke, thence through a steam boiler where the hot gases transfer the heat to the water in the boiler circulation and convert it into steam.

The glowing coke is conveyed to the sealed cooling chamber, and the air of the system, including that entrained in the interstices of the coke mass, is put into circulation by means of a fan.

When the system is first started, a small portion of the coke is converted into a mixture of carbon monoxide and carbon dioxide, the percentage of each depending on the temperature at that particular time. However, the oxygen of the encased air is quickly consumed, and a mixture of inert non-combustible gases remains. This mixture of gases, in passing through the glowing coke, absorbs its heat, which is carried to the adjoining steam generator. The cooled gases leaving the boiler are conducted back to the fan and again forced through the glowing coke. The coke is drawn off from below which is the coolest zone, and fresh charges of glowing coke are introduced from above.

In this manner continuous performance is established, and by regulating the fan speed, a relatively close relation may be maintained between the cooling of the coke and the generation of steam.

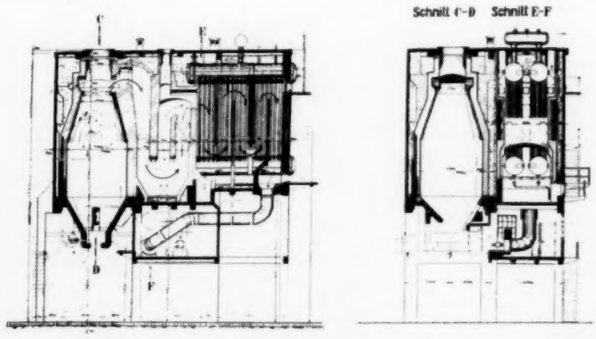

FIG. 1—Diagrammatic Longitudinal and Cross section of a Dry Coke Quenching plant of 350 tons per day.

The possible loss of coke through burning has been determined by numerous tests to average .04%, a quantity practically negligible, even if greatly increased.

The principal benefit, of course, in Dry Quenching is the production of 400 to 450 pounds of steam per 1,000 pounds of coke quenched. The Rochester plant over a period of six months averaged 420 pounds of steam per 1,000 pounds of coke quenched, so that it is quite apparent that a dry quencher is a real investment; and in most cases, it will amortize itself after a period of approximately four years. After this amortization is completed, there is, of course, a clear profit of the equivalent of 840 pounds of steam per ton of coke, and although present steam requirements in the plant may be met from waste heat, or the burning of breeze, it is quite possible where breeze is burned for steam production, to free this for sale to industries in the community; or in

*Presented before Combustion Engineering Section, March 29, 1928.

†Combustion Engineering Corporation, New York, N. Y.

"Fuel Savings Confe

Held Under the Auspices of the Combustio

A. I. & S. E. E., At the Edgar Thomson Works of the Carnegie S

"Fuel Savings Conference"
Being Held Under The Auspices Of Our Combustion Engineering Section At
Thomson Works Carnegie Steel Co. Braddock Pennsylvania Thursday March 29, 1928

"Fuel Savings Conference,"

Held Under the Auspices of the Combustion Engineering Section of the
At the Edgar Thomson Works of the Carnegie Steel Co., Braddock, Pa., Thursday, March 29th, 1928.

, 1928.

the case of waste heat producing sufficient for present requirements, it is quite possible in many cases to use the steam from the dry quencher for the manufacture of power, which either may be used around the plant or fed into the local power company's lines. In any case a clear gain is to be had.

The specific heat of coke is not exactly known. It depends upon the temperature, the ash content, and upon the amount of volatile matter still contained in the coke.

The thermal efficiency of the plant is about 85 to 90%, and there is no less due to combustible matter in the ash, stack waste gases, etc., as is the case in direct fired boilers; the only loss is through radiation.

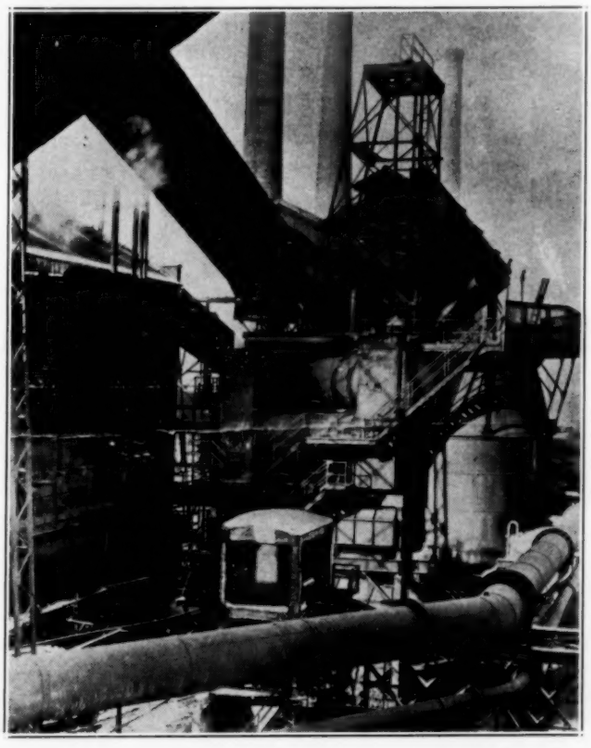

FIG. 2—Dry Coke Quenching Plant of 425 tons per 24 hours at the Gas Works of the Rochester Gas & Electric Corp.

Another great advantage of the Dry Quenching system lies in the fact that dry coke has a higher heat value due to absence of water.

In burning wet quenched coke, a certain amount of coke is uselessly wasted for the purpose of evaporating the water in the coke. This water content can be anything between 3 and 15%,—the higher figure referring to the drowning process, whereby the whole carload is drowned in a water basin. With a coke of 10% water, a fuel saving of about 11% may be expected if the moisture is eliminated.

Improvement in the quality of the coke facilitates the selling of this fuel and widens its field of employment. Gas coke could compete very well with coke oven coke in the field of general heating if its moisture content was lowered or eliminated. Tests which have been made with dryband wet quenched coke in domestic heating furnaces have proved the superiority of dry over wet quenched coke. Even the smallest gas works with a daily output of about five to ten tons have already adopted the Dry Quenching system for the reason that they were able to sell their coke easily.

Although it looks profitable for the gas works to sell water with the coke, as a matter of fact, customers who have experienced the higher quality of dry quenched coke, prefer it, even though they have to pay a higher price for it.

In transporting coke containing 10% water, the freight for every tenth car would be paid uselessly.

Whether the dry quenched coke is stronger than the wet quenched depends upon the coal from which it is made, and upon the method of wet quenching with which Dry Quenching is to be compared. Many tests have shown that the dry quenched coke is stronger and has less breeze than the wet quenched. The plant at Rotterdam shows a breeze reduction of from 14 to 6%; and the reduction at the Utrecht plant is about 2 to 3%.

The Gas Works and By-product Coke Works, themselves, are benefited by the advantages of the dry coke. Eighteen to twenty per cent of the coke made is used in the producers for making heat gas for the coke ovens. The higher thermal value of dry coke effects considerable savings in the producer operation.

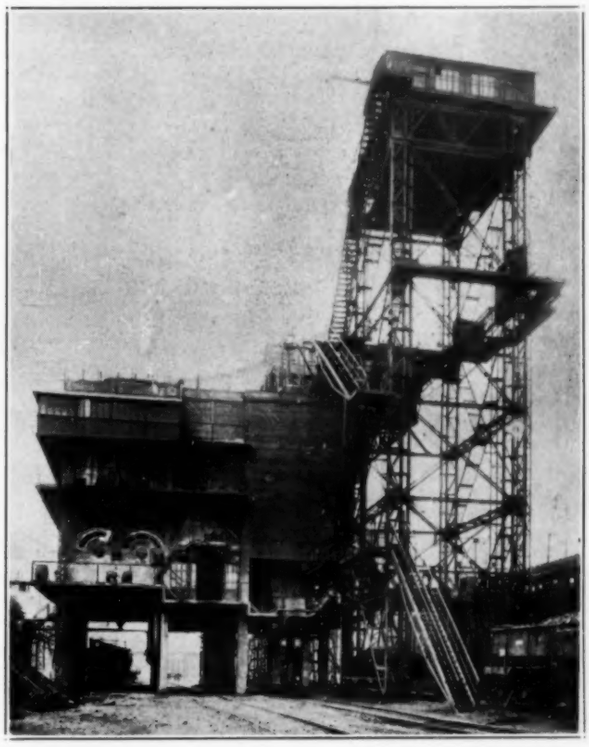

FIG. 3—Dry Coke Quenching Plant of 1000 tons per 24 hours at the Coke Works of the Forges Et Acieries De La Marine Et D'Homehourt, France.

Another saving is obtained in using dry coke in water gas plants.. Beebee's test shows a saving of 6.3% when the water gas plant was supplied with dry instead of wet coke of 4% moisture. This saving is higher than would be expected, and may have its cause in the fact that not only the heat value of the fuel, but also the temperature of the fuel bed

are responsible for the efficiency of the water gas process. The evaporation of the moisture contained in the wet coke cuts this temperature down. By wet quenching coke the moisture is sucked into the innermost parts due to the contraction of the gases in the pores when cooling down. Thus the moisture is kept obstinately in the heart of the piece, and will only be given off when the coke reaches higher temperatures. In the case of the blast furnace process, that means a great part of the moisture of the coke will only be released when the coke has already reached the lower zones of the cupola cutting down the temperature. This may be a plausible explanation for the fact that the two European steel works which use dry coke in the blast furnaces, i. e., Homecourt in France and Witkowitzer in Czecho-Slovakia,

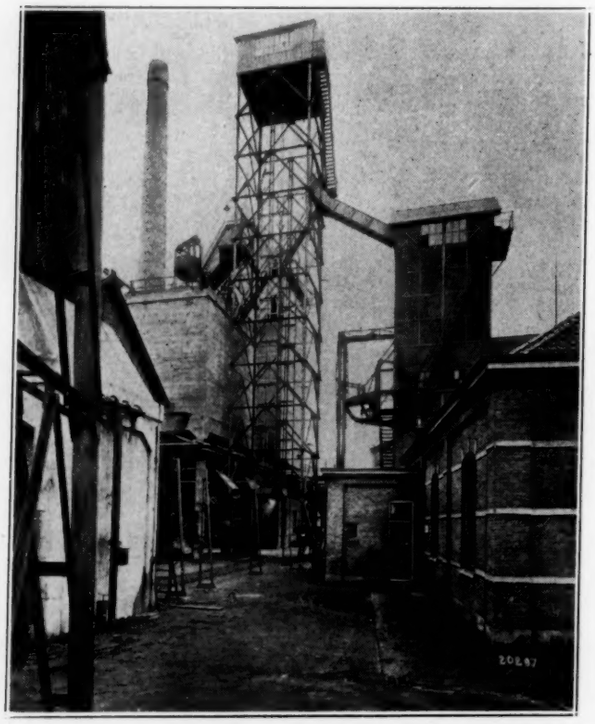

FIG. 4—Dry Coke Quenching Plant of 216 tons per 16 hours Hoist and Screening Plant at the Municipal Gas Works of Utrecht, Holland.

make considerable savings in fuel and speak highly of their experience with dry coke in blast furnace operation.

E. C. Evans of the National Federation of Iron & Steel Manufacturers in England, reports regarding the Homecourt plant:

"It is difficult to estimate the fuel saving in the blast furnace operation, but a reduction of approximately 100 kilos per ton of pig iron produced has been effected."

This is about 10%. Another author reports a saving of 4.17% (Dr. Muller-Karnap).

Trouble with dust forming pockets in the cupola is greatly reduced, due to the fact that this coke having already received a certain mechanical handling in the dry quencher is stronger and does not break up to the same extent as wet quenched coke going down the cupola under the pressure of the load. It is modern tendency to handle the coke mechanically and sieve off the breeze before charging into the blast furnace.

Besides these economical and technical improvements, these steel works benefit by the saving of steam produced by the dry quencher amounting to about 860 pounds per ton of coke.

For foundry purposes many advantages may be derived from the use of dry quenched coke. It is a well-known fact that a cupola charged with coke that is thoroughly dry, works more rapidly, while on the contrary, with coke dampened by rain during transit, the capacity of the cupola decreases visibly. In this case, and wherever the fuel is used only for the generation of heat, the higher thermal value of dry quenched coke is fully available.

In most of the works, the steam is used in the by-product plants with a pressure of about 90 to 170 pounds. In other works, the steam raised at a pressure of about 230 to 300 pounds square inch, superheated to about 650 to 700° F., is used in turbo-generators furnishing electric power for the works.

In one plant (Utrecht) producing about 240 tons of coke a day, the dry quencher furnishes all the steam and all the electric power for the works, and a surplus of electricity is sold to the municipal light and power station. There is no other boiler in operation together with the dry quencher. A gas fired boiler, however, is installed making steam during the 8 night hours when no coke is drawn.

First tests on Dry Quenching were made by Sulzer Brothers in 1918 on a 25 ton plant.

The first commercial plant was put in operation in the Rotterdam gas works in 1922 with a capacity of 100 tons in 16 hours.

At the present time twelve plants are running; the largest of 1,000 tons a day, the smallest 15 tons a day. The small one is a new type just put into operation in connection with a vertical retort oven plant.

Two plants are under construction: Glasgow 300 tons, and Victoria Mathias Mine, Essen, 500 tons.

The operating cost of Dry Quenching plant is low. The power consumption is about 3 k.w.h. per ton of coke for fan and hoist together.

Usually no more labor is necessary, and the cost for maintenance and repair not greater than for wet quenching.

To sum up, compared with wet quenching, the Dry Quenching of coke has a number of economic advantages, among which are the following:

1—Steam generation from heat otherwise wasted.

2—Greater income through increased quality of coke, due to the absence of water.

3—In many cases greater income through increased proportion of coarse coke, due to reduction in amount of fines and coke breeze.

4—Advantages in blast furnace producer and water gas plant operation.

5—Reduction in transportation cost, due to absence of water.

6—Reduction of maintenance costs of coke transportation equipment, steel and concrete construction, etc., due to absence of wet, corrosive, quenching vapors.

DISCUSSION

E. W. Trexler*: One noticeable feature in the pictures shown was that most installations were made up of several units. What is the maximum size of unit they recommend?

Walter Sennhauser†: That was back in 1922 when we made four units for a thousand ton plant, each for 330 tons per day, one to act as a spare. We are now designing a plant for 1500 tons in one unit. I should think, that as a maximum, we would go up to 2000 tons per unit.

John N. Reese‡: It looks to me as if they handle the coke somewhat more roughly than they would in the usual method of quenching where they quench and put the coke on an inclined platform and conveyor. I would like to ask whether you have any tests on the amount of breeze produced when they used the old style quenching system and then changed to the dry quenching system; whether more or less breeze was produced?

Walter Sennhauser: Usually less. In Rotterdam, they have had 14 per cent of breeze with the wet quenching process. The dry quenching porcess resulted in a breeze reduction of 6 per cent, i. e., from 14 per cent to 8 per cent. In another plant, the breeze was reduced about 2 to 3 per cent. The plant at Rochester, however, shows an increase in breeze if wet and dry quenched coke are compared when they lie on the coke wharf. If compared after the crusher, the amount of breeze is not higher than with wet quenching. The breeze formation with the dry quenching process depends on the layout of the plant. At Rochester, the space available was at a premium. The coke is handled too roughly there on account of the very steep chutes and other unfavorable local conditions. At other plants where there is plenty of room for chutes allowing the coke to run smoothly, we usually have less breeze than with wet quenched coke.

John N. Reese: What is the relative size of the coke after dry quenching and after wet quenching? The reason I am asking these questions is that it seems to me from what I have heard the coke must undoubtedly be handled more roughly by the dry quenching system than by the wet quenching system.

Walter Sennhauser: Usually the dry quenched coke is more uniform in size. The big pieces break up, but there is no increase in breeze. The blast furnace people in Europe have no objection to that —they like uniform coke. They consider it an advantage to have the big pieces broken up and to have the coke uniform in size.

John N. Reese: That would be an advantage where you have a dense coke. When we designed a certain by-product coke plant we put in a rotating grizzly to screen the coke in the assumption that the coke should be handled more or less roughly to take out the breakage of which the coke is capable so the blast furnace would get coke no longer breakable. You claim that is an advantage with the dry quenching system?

Walter Sennhauser: Yes. The big pieces are broken up going down the cupola.

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†Chief Engr., Dry Quenching Equipment Corp., New York, N. Y.

‡Asst. to Gen. Supt., Pittsburgh Steel Co., Monessen, Pa.

John N. Reese: Is any of this coke used on those blast furnaces in Germany that are producing the large tonnages at the present time, with low blast pressure and good coke rate?

Walter Sennhauser: In Germany, there is no steel works using the dry quenching system. There are works making dry coke for domestic purposes and foundries, but I do not know of any dry quencher used in Germany in connection with steel plants. There is a steel works in France that uses the dry quenching system for cooling coke made from Sarre coal. This is a sandy coal, and is blended in order to get a good coke. They have a great advantage, they claim, in dry quenching the coke. They had quite a lot of trouble with dust in the blast furnace, but after adopting the dry quenching system a somewhat smaller coke was produced with fewer large chunks and less breeze. This diminished their trouble with dust pockets in the blast furnace.

John N. Reese: In American blast furnace practice we place a certain amount of water in the furnace charge, which, of course, augments the amount of water charged with the coke and the ore. Therefore, I doubt whether the advantage claimed with dry coke would be realized in the usual American practice. In other words, charging dry quenched coke with practically no moisture would result in higher top temperature and resulting losses in the blast furnace which would offset any advantage that might be gained from charging with dry coke. Would that be true?

Walter Sennhauser: Blast furnaces in Europe charged with dry coke do not show higher gas temperatures on top of the furnace. There may be a higher temperature further down in the furnace, but not on top.

R. H. Schaller*: I do not believe that I can add anything, but I would like to ask a few questions. I heard Mr. Beebe give an article on dry quenched coke approximately a year ago, in which he stated that the strength of the coke was not altered by the dry quenching as compared to the wet quenching. The dry coke was handled roughly and was smaller than the wet quenched coke due to the increased handling. For their producers it did not make any difference. He did not however give any data on better producer efficiency with the dry quenched coke at that time. I would like to get such information this afternoon.

There is a certain amount of desulphurization of the coke taking place with the wet quenching that does not take place with the dry quenching. I question the 10 per cent coke decrease with the use of dry quenched coke. Practice at many furnaces is to add water to the charges going into the furnaces. I cannot conceive of drawing water into pores of the coke and being entrapped without escape. From what coke experts tell us, the porosity is such that the pores are open and interlock or intercommunicate. If it is true that moisture is entrapped in the pores of coke wet quenched and coke is used in a blast furnace, then it seems logical that the combustion is retarded and the top furnace temperatures will be lowered. I cannot see there,

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the advantage of the dry quenched coke for the furnace.

The furnaceman charges his coke into furnace by volume, but checks back to weight, and instead of 2 or 3 per cent moisture coke, if using dry quenched coke, he will have 2 or 3 per cent more coke in his furnace instead of water as paid for as coke.

I do not believe there are many furnaces in this country using 15 per cent moisture coke, that is as delivered by wet quenching at the coke plants. If there are, the coke plant operation is far from being up to standard practice.

Just for the protection of the plant against a wet quencher, it seems a considerable amount of money invested. It is hard to say if it is justifiable or not.

The steel structure around a steel plant needs more attention than steel structure not as closely located to steel plants. A little more attention to he selection of paint and painting for steel work around quenching stations will suffice to put it on a par with other steel structure. The small increase of the rust that takes place around a quenching station is nominal compared with the first cost of installation of a dry quencher.

It is, however, a step in the right direction, if a certain amount of heat can be saved and made into a certain amount of steam. There is a limit of the steam that can be produced depending entirely on the amount of coke that is put through the units.

The question has been answere dabout the size or limits for construction of these units.

Walter Sennhauser: The statement that Rochester has found that the wet quenched and the dry quenched coke have the same strength when both have had the same mechanical handling may be true. It depends on the coal from which the coke is made. The dry quenched coke has had more mechanical handling than the wet quenched and it appears therefore stronger—it is already broken up. In that steel works in France where they use coke made from Sarre coal, they found that the coke is stronger when dry quenched than wet quenched. Homecourt has a saving from the coke quenched in their thousand-ton plant and I was told that if they did not have the plant they would build one immediately. I feel sure that there are cases where there is not a great difference between wet and dry quenched coke as to its strength, but there are other cases in which the difference is great.

About the saving in the blast furnace operation, I might say that we do not have much of an explanation for it. I tried to explain it, and it may be that later this explanation will be changed, but there is actually a saving. One author says 200 pounds per ton of pig iron; another says, about 4 per cent; others 2 or 3 per cent. It is hard to find exact figures on savings in blast furnace operation because so many variables must be taken into consideration.

Regarding maintenance and repairs on and around the plant: We all know that wet quenching vapors destroy a great deal of steel and concrete in the neighborhood of the quenching station, and we should think it obvious that with dry quenching these maintenance costs are decreased considerably. Whether or not investing the money for a dry quenching plant is justified, depends, of course, upon the economical aspects of the plant.

In steel works, the economy of the dry quencher depends not only on the steam price, but also on the saving in blast furnace operation.

About the saving in the Rochester Water Gas Plant: They have made tests with their water gas plant running it 14 days with dry and 14 days with wet quenched coke of 4 per cent moisture. The test showed a saving of 6.8 per cent in favor of the dry quenched coke.

W. B. Chapman*: How frequently is gas circulated? Take the entire contents of the container, how frequently is it emptied and filled again, and how long is the coke in the container?

Walter Sennhauser: The cooling time is three to four hours; in that time the coke passes through the whole container. The gas circulated in the plant is always the same. Only when we charge and discharge coke, we get a little air into the system according to volume of discharged coke; but if you figure out the amount of coke consumed, it is around .04 to .05 of 1 per cent. Therefore we can say that practically always the same gas is in the container.

W. B. Chapman: How often does it go round and round?

Walter Sennhauser: That depends on the section of the gas flues and the gas volume of the plant. We only figure out how much gas we have to circulate per hour, and I have never figured out how often the same gas is circulated through the charge.

R. S. Coulter†: How are explosions prevented when the door is open at the top?

Walter Sennhauser: The cooling gas sometimes contains hydrogen due to the fact that the coke is not completely degassed. We have had no explosion. We do, however, protect the plants by using safety hoods. You must consider that the whole system is entirely closed. There is a stream of gas circulating in this closed system and if we open only one door at a time, no gas goes to the atmosphere and no air enters the system. There is only an adjustment to the atmospheric pressure, but the case would be different if we would open two doors at the same time. Then air would be drawn in through one door and gas pushed out through the other. Means are provided that one door only can be opened at a time. If the top door is open the hydrogen in the container burns out without doing auy harm.

L. C. Lucas‡: As the circulating gases give up their heat in the boilers, what happens to the steam as the coke cools?

Walter Sennhauser: There is a fluctuation not of the steam pressure, but of the steam generation. This fluctuation is not large enough to do any harm. There is always a multitude of loads in the container. We do not cool down one single load and then fill in another one. If there are 6 to 20 loads

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†Fuel Engr., Bethlehem Steel Co., Sparrows Point, Md.

‡Works Engr., American Steel Foundries, Granite City, Illinois.

in one container, the difference in temperature of the gas at the outlet of the coke varies about 300° F. between charges. This does not affect the steam generation to a great extent. There is, of course, a fluctuation, but it does not amount to much. I might add that in the plant at Utrecht, (Holland) where the steam is used for generating electricity, the steam turbine runs all day long and the fluctuations of the steam generation do not cause any difficulty.

*The Application of Pulverized Coal to Industrial Furnaces**

By W. A. SHOUDY†

MY most intimate friend is an architect, with whom I graduated as a Mechanical Engineer. He is by heredity an artist to his finger tips, while the artistic part of my brain is an absolute void. Our view points are consequently as far apart as are the poles of this earth, but our common early training forms a bond which though much attenuated, frequently draws our thoughts to a common meeting ground.

Many years ago we were discussing the necessity of the hand of a Master for the production of the perfect beauty of a work of art, when I said to him:

"If you had a complete knowledge of the sciences underlying the blending of colors, the behavior of pigments and oils and of psychology you could reproduce old masters on a production basis as Ford makes flivers."

Of course he raved, for it may be centuries before we can codify all the laws governing the creation of a work of art, but only a few weeks ago he said: "There is an engineering basis for beauty in architecture and perhaps in other arts. Beauty is what our subconscious mind tells us is right. For centuries pilasters have been used for supporting thin walls. Today these walls are but curtains between columns of steel and pilasters are used to beautify these columns. When we view the finished building our subconscious mind estimates the strength of the pilaster, as if its strength were in masonry instead of steel, and if it "looks too thin" or it "looks too thick" it is not beautiful. The engineering is bad and beauty is lacking."

Twenty years ago when guarantee tests were to be made of a boiler, a picked fireman tended the fires. He knew nothing of CO_2 or B.T.U. He judged by the looks of the fire, having learned the trick by long experience and aided by a natural aptitude. He was an artist, born and trained. He knew the how but not the why. CO_2 meters and steam flow meters, thermometers and draft gauges were gradually developed, and now the boiler is controlled at the instrument board and in some cases automatically with resulting efficiencies higher than the practical fireman could hope for.

The laws of combustion for boiler furnaces have been pretty well defined and the science has succeeded the art. These basic laws are the same in all combustion processes, but the application of the resulting heat differs in every industry and except in boiler practice, is still very much more of an art than a science. When we have collected the data showing the behavior of the materials under heat with products of combustion, we will be able to design an industrial furnace as easily as one for a boiler.

Let us therefore first consider the science of combustion by studying boiler practice where the advance has been most rapid, and then attempt to apply these principles to industrial furnaces.

The combustion problem is simple in fundamentals, but complicated by extraneous difficulties. It is that of burning carbon, hydrogen and some sulphur in such a way that a desired temperature is obtained in a specified zone. It would be simple if only these elements were delivered to the furnace, but it is complicated because they are only available commercially in company with inert matter. Clean gas is nearly ideal because the desired elements appear as molecules, separately or combined, accompanied only by inert gases which reduce the theoretical temperature. Clean oil is inferior only because the molecules are not separated, hence the oil must be atomized or vaporized.

All other fuels carry other and useless matter—water and ash which sometimes are as innoccuous as deadhead passengers, but often so troublesome that the laws of combustion must take second place to the laws governing this excess baggage. The water merely reduces the heat available, but the characteristics of the ash absolutely dictate the maximum temperature and the disposal of the products of combustion.

Coal is the subject of this afternoon's discussion. I have mentioned gas and oil only to more readily point out the action of perfect combustion. With coal this perfection is never reached, partly because it is a solid, but principally because the excess baggage that it carries into the furnace is exceedingly troublesome.

Combustion can only be produced by bringing the fuel and air together. To do this we must break coal up into molecules. On a flat grate or stoker this is done by first distilling off the volatile molecules, then the carbon cracks from the heat, producing greater surface for contact with the air and gradually the coal disintegrates leaving the inert matter, or ash. Because the air spaces in the fire bed are restricted, the air moves at a high velocity, scrubbing away the products of combustion and leav-

*Presented before Combustion Engineering Section, March 29, 1928.

†Associate Professor of Mechanical Engineering, Columbia University.

ing a clean surface to combine with the oxygen that follows.

Frequently there is not sufficient time to complete combustion in the fire bed, hence the gas above this bed is largely carbon monoxide and hydrocarbons. If the percentage of hydrocarbons is high, considerable time is taken for all the molecules to find the necessary molecule of oxygen—hence the flame is long. The same principle applies with pulverized coal flames where long and short burning coals are known for the same reasons and this factor should be considered in the adaptation of pulverized coal to industrial furnaces, due to sometimes excessive carbon losses with long burning coal. Sometimes the admission of air over the fire bed, particularly if at high velocity, so as to penetrate the gases, results in a shorter flame, permitting of smaller furnace volume. This has been demonstrated by Mr. Grunnert's experiments with over fire air in the Commonwealth Edison boilers, and by the use of the rear arch in burning anthracite. The large bulk of coal and volume of air to be handled makes it impractical to thoroughly mix the air and combustible gas, consequently more air is delivered than theoretically required. This excess air carries out useful heat, thus reducing furnace temperature and efficiency.

When we burn coal in a pulverized form, we endeavor to break it up into molecules, but come far from succeeding. The process must therefore continue in the furnace, some coals extending the surface by a puffing up—coking—action, and others breaking up mechanically.

Anthracite is an excellent example of the other extreme. It is not only very difficult to pulverize, but it breaks up under heat very slowly. This together with the low percentage of volatile molecules makes it very difficult to burn in a pulverized form.

This subdivision into molecules takes time, hence the particles, must remain in the furnace a relatively long time, and such furnaces must be large. If the velocity of the air with respect to the coal is small, or if the particle is relatively large, the path of the coal in the furnace must be long because much time must be allowed to complete combustion. The flame therefore will be long and luminous. If we can make the coal go in one direction and the air in another, the CO_2 is quickly wiped off the coal, increasing the rate of combustion, the temperature of the flame, and the breaking up of the particles. The flame therefore becomes shorter and more transparent. This is why the turbulent burner is becoming so popular. The flame is shorter, and combustion volumes can hence be reduced.

A similar result is obtained by reducing the size of the coal particles. The time required for combustion is shortened, hence the incandescent section of the flame is reduced and the whole flame shortened.

The type of flame and the size of the furnace therefore is dependent upon the turbulence of the air and the fineness of the coal. Unfortunately, no definite relationships have yet been defined. Of these factors turbulence has the widest range of variation, but fineness has a fairly definite lower limit depending upon whether or not the coal has a coking characteristic. 95% through a 40 mesh is the coarsest coal desirable. Heavier particles fall upon the hearth where the carbon is burned out leaving an extra 5% of ash in addition to the normal 20% deposit. The increase in ash deposit on the hearth of heating or heat treating furnaces is sufficient to produce a sticky and unmanageable bottom that results in lowered production and increase scrap losses.

The specification for fineness depends upon the mechanical properties of the coal and its cooking action. Anthracite should be ground as fine as possible, but the power for grinding and high maintenance cost of the mills have pretty well defeated its burning in a pulverized form. Some of the harder bituminous coals also, particularly those containing pyrites, require so high a power cost that coarser coal is burned, the loss in efficiency not being so great as the increase in power costs.

I have not specified the percentages of the finer sizes because this percentage varies with the coal and is not always within the control of the pulverizer. For a complete knowledge we must know the percentage of superfines, those particles smaller than 200 mesh, more nearly approaching the molecule.

Were it not for the behavior of the ash, furnaces might be operated at any desired temperature below the theoretical by varying the per cent of air admission. Fortunately the temperature at which this ash melts is the principal factor that must be known, and this is easily determined. The chemical analysis of the ash is desirable but the fusing temperature generally indicates the chemical composition with sufficient accuracy for combustion purposes.

In boiler practice the effect of the molten ash on the setting and gas passages are the limiting factors. An ash of low fusing temperature when carried into the tube bank solidifies on the tube often closing the passages and stopping operation. If the velocity of the gases is decreased they carry less slag. This results in reducing boiler output, or requires changing baffling. Passing the gases through a colder zone, as with a slag screen, helps, and some times increasing the length of the furnace has solved the problem. As yet we have not sufficient definite information to accurately forecast results.

A low fusing ash generally contains sufficient iron to act as a virulent flux on contact with a brick setting, actually washing away the surfaces as fast as they come in contact with the molten ash.

The only solution to this problem is chilling the ash. This may be done by air or water cooling the walls, or by increasing the air for combustion and thus reducing the furnace temperature.

These are fundamental considerations that govern any combustion problem. The next phase is that of the utilization of the heat. The central station wants high efficiency, because coal is the largest single operating cost. Expensive equipment can be easily justified. The units are so large that labor is small and a high wage rate can be paid. College graduates are often employed for this work. They are the key men in plant economy. Such plants must use the coal available in the territory, and the plant is designed accordingly.

The controlling factors in industrial furnace design are revised. Production comes first with labor and fuel secondary. Temperature and atmosphere are therefore of more importance than fuel economy.

With liquid gaseous or pulverized fuel, temperature control is ideal, with possibly pulverized coal to be preferred because its flame is more mellow.

Temperatures may be varied at will, by varying the air. High temperatures require small air ratios, low temperatures high air ratios. Extremely low temperatures, as in drying, can be obtained by admitting secondary air after combustion is completed. This is one reason why coal in pulverized form is so perfectly adapted to industrial furnaces. The ease of regulation both coal and air makes temperature control ideal, and the flame may be made long or short, luminous or clear by changing air ratios or burners.

Industrial furnaces, however, require constant temperatures throughout each portion of the operating cycle. Overheating is eliminated by ease of operation and accurate control. Burning of the product is also eliminated by the elimination of excess air and flame regulation. This point indicates an advantage of the bin and feeder system over the direct fired unit system. For the latter a constant flow of air is necessary regardless of the quantity of coal that is required to keep the mill clean and operating properly.

There are two methods of burning pulverized coal: First, the central system, and second, the unit system. The central system was borrowed by the boiler operators from industrial furnace practice, while the unit mill was developed for boiler purposes and now has been adapted to industrial furnaces. There are distinct advantages for each system, as well as fairly distinct fields.

Where there are numerous furnaces to be supplied with relatively small quantities of coal, the central system is preferred. When the furnaces are few and quantities large, the unit mill is often preferred. In the neutral ground between, both types have been used.

The central system appears more complicated, but only because every precaution has been taken in its design and every type of coal can be used, whereas some coal cannot be used with the unit system.

Unit systems supplied to a number of furnaces in one plant represent a corresponding number of sources of possible trouble as well as a number of different grades of coal finenesses. A central pulverizing plant centralizes any possible mill trouble, produces a uniform fineness of coal throughout the plant and insures a supply of coal at each furnace during any changes that may be required at the mill or by emergencies. This is particularly important where melting is concerned. It is absolutely essential that sufficient fuel be on hand to avoid the freezing of the bath. Should this occur, great difficulty will be experienced in remelting the solid cake of metal.

The central system requires a crusher, dryer, pulverizer, transport system, and at each furnace a storage bin. It has the advantage of centralization at the point where coal can be received. The coal generally is pulverized to a more continuously uniform fineness. It may be shut down for short periods without affecting furnace operation and since the pulverizers operate at full capacity, the power cost is lower.

Although pulverized coal with four per cent moisture has been known to cause no trouble in transport systems or bins, a limit of two per cent is preferred, consequently driers are necessary with the central system.

Inasmuch as the unit mill delivers the coal direct to the furnaces, moisture only affects furnace temperature. Consequently unit mills can operate with the usual coals, without driers. It is becoming customary to introduce hot air from the furnace wall into the mill, thus adding the drying of the coal. The principal effect of moisture is to reduce the capacity, or fineness of the unit mill product.

In speaking of moisture, we must differentiate between surface and the inherent moisture. Inherent moisture seems to cause no trouble. Coals with 15% inherent moisture may be pulverized in a unit mill if the coal is air dried, but 10% surface moisture may cause trouble. 10% to 12% surface moisture with air preheated to about 350 degrees, seems to be about the limit for unit mills, higher preheat sometimes causes tar trouble with the coal.

Unit mills seldom operate at full capacity, consequently the power per ton is higher than with the central system, but this cost is somewhat offset by the power cost of the transport system of the central system. The initial first cost for unit system is low, but the results cannot be compared with those obtained by central pulverizing plant in case of operation, maintenance, flexibility and shut-down charges.

Depending upon the type coal, there is a variation of fineness with the unit mill, due to wear. Directly after changing hammers as bad charge, the finest coal is produced, this gradually falling off till the next repair period. This is not a serious objection, for with reasonable inspection, repairs can be made often enough to avoid serious change in fineness.

Although the explosive hazard is undoubtedly greater with the central system, it is negligible with a well designed system. Pulverized coal is highly explosive, for otherwise we could not burn it in a furnace. But the same can be said of powdered sugar, and fuel oil is a great fire hazard. Cheap construction, light materials and poorly made joints cannot be used with safety. The Rules of the National Fire Protection Association are reasonable, and if followed insure complete safety. We cannot condemn pulverized coal because some have been careless in its use.

Burner design seems to be the least important point for study, inasmuch as cost is so small an item of the total "home made" burners show little economy. There must be sufficient area to pass the coal and its transport air preferably in the center of the stream of all the remaining air required. If the air is given a rotary motion on entering the furnace, the turbulence thus set up completes combustion before the furnace charge can cool the gases below ignited temperatures.

But turbulence in a burner means nothing unless the turbulent action can be maintained in the furnace. Some turbulent burners are high power consumers and poor result producers for this reason. The turbulent burner to be effective must cause sufficient disturbance in the flame within at least 8 ft. from the end of the burner to produce a thorough mixing of the coal with the necessary air for combustion.

It is desirable to make the means of regulating both air and coal as simple as possible and adjust ments should permit of moving the mouth of the coal pipe in or out of the furnace opening, so as to regulate the length of the flame.

The wrong type of coal has been known to ruin an otherwise perfect installation. It must be remembered that the ash of pulverized coal is carried over with the other products of combustion. Just what effect this ash has, has not been determined, but it is obvious if the ash fuses below the temperature of the charge in a heating furnace it will adhere to the material where as a higher fusing ash would remain as a dust.

The ash that fuses below the temperature of a melting furnace will flow out of the tap hole with the slag from the iron and will give no trouble. An ash of higher fusion temperature may cause trouble in the product that it adheres to if it solidifies above the working temperature of the metal. The fusion point of the slag referred to here means the temperature at which the slag becomes liquid. Due to the velocity of the flame through the furnace only a small percentage of the ash settles out. The coarser the coal the more readily the coal particles will settle to the hearth where they leave their ash.

There is an opportunity for valuable research to determine effect of the ash on slag. Little is known about the subject at this time. If the coal is sufficiently pulverized the ash particles are so fine that they do not settle even though fused. It is therefore safer to go to the extreme in pulverizing if there is any doubt about the quality of the ash. I know of no cases where 85% through a 200 mesh screen has not proved satisfactory.

The design of the furnace is of course important, and here we must depart somewhat from boiler practice. The boiler furnace is a combination of gas producer and combustion chamber. It is made as small as possible, approximating a cube, generally with one side heat absorbing. Although the lower boiler tubes absorb a great deal of radiant heat, it is not enough to seriously affect furnace temperatures. The walls after becoming heated radiate heat to the colder parts of the furnace and help support combustion. The cubical form of furnace permits of tight walls, and a minimum of doors, hence suction can be maintained within the furnace without serious air in filtration and no attention need be paid to oxidizing or reducing atmospheres.

A large metal furnace is long and flat, with a very large radiant heat absorbing surface, in the form of the bath, which does not support combustion. Consequently, combustion must be complete before entering the furnace proper. The side walls are not as tight as with the boiler, and if a reducing atmosphere is required air infiltration is disastrous. Consequently a slight plus pressure is desirable. If for an oxidizing atmosphere, air is admitted through the side walls, the cold air will remain at the bottom, blanketing the hot gases from the metal. Such a stratification is very common in boilers, the several stratas of gases passing through all passes scarcely mixing in spite of the turbulent action of the tubes.

The question of roof height is largely a matter of providing area to insure correct velocity for the gases, the shape being dictated by the particular use of the furnace. 10 ft. per second seems to be a satisfactory velocity for general purposes.

The duty of the stack serving the furnace should therefore be merely that of carrying off the products of combustion. The air should be supplied by other means and all should enter with the fuel, thus insuring the correct proportions and complete mixing, so as to produce a uniform gas mixture throughout its travel.

Another feature of furnace design borrowed from boiler practice, is the use of the suspended arch in place of the sprung arch. This type has become universal in boiler practice because of the longer life under the extreme temperatures of boiler furnaces, and has been developed also into a suspended side wall construction. A number of these suspended industrial furnaces are now in use and are showing longer life and greater ease of repair than the old style and hence becoming increasingly popular.

Coats must be divided intto two divisions—capital expenditures and operaitng costs. The first varies widely and is influenced so largely by local conditions that just comparisons can seldom be made. For example: unless good engineering judgment is used in designing the raw coal transportation system this item alone may become excessive and defeat an otherwise sound project. Operating costs can be more readily compared. The B.t.u. fed to the furnace in the form of pulverized coal, oil or gas will be substantially the same for all these fuels. Claims have been made for slight differences in favor of each, but they are slight and the tests are not always strictly comparable. The fuel cost therefore becomes a matter of buying the largest number of B.t.u.'s for a dollar. There is a decided saving in cost of pulverized coal over grate combustion, because of the higher combustion efficiency, due to the better air regulation and negligible carbon loss. This saving is somewhat offset by the power cost of pulverizing.

The net saving on a series of faggot heating furnaces over hand fired including such items as coal consumption, coal cost, coal for heating furnaces during layover period, increased steam production, reduced furnace loss, reduced furnace maintenance, cost of coal preparation, interest and amortization, increased furnace production, amounts to 49% of the investment required for equipping these furnaces with pulverized coal supplied from a central pulverizing plant. While with a similar application to a series of copper melting furnaces, the savings estimated from recent tests covering all the above items over oil firing on the present low oil prices amounts to 24%.

Much of such data is of a confidential nature, hence cannot be included in such a paper as this. I am mindful of the fact that some articles and papers state that the use of pulverized coal has resulted in increased total expenses because of rapid erosion of refractories. Yet just recently a copper furnace has shown longer life with pulverized coal than with oil. Most of these failures, I believe, have been due to insufficient study before the installation, for the fact, in this country, two hundred pulverized coal installations, supplying 2500 industrial furnaces are in successful operation, is sufficient indication that this system can be made successful.

I have not attempted to discuss furnace design in detail, partly because of the wide variety of furnaces, but principally because you are far better equipped to discuss this subject than I. I have attempted to point out only those basic principles which are definitely known and which must govern your designs. It is rarely possible to copy details except when fuel and product are identical. This is true for boiler furnaces and still more important for industrial furnaces. Most of our failures have been due to copying of details. If we are to succeed we must go back to first principles and for the present at least, design each new furnace "from the ground up."

DISCUSSION

Henry Kreisinger*: The first point brought up by Mr. Shoudy was the size and the shape of powdered coal particles. He presented some slides showing that the particles of powdered coal varied greatly in size, some were very small and some comparatively large. They had all kinds of shapes except spherical. There did not seem to be any spheres among the particles of powdered coal.

If we take the different sizes of powdered coal as obtained by sieve analysis and measure each size, we shall find that the average size of the coal particles will be about 1/500 of an inch. This at first looks like a very small particle, but as Mr. Shoudy said, it is very large compared with the size of molecules of oxygen with which this particle of pulverized coal must combine during the combustion process, and a very large number of the oxygen molecules are required for its complete combustion.

In order that the oxygen molecules may combine with the coal particle they must come in contact with its surface. If we depended on natural diffusion to bring the oxygen molecules in contact with the surface of the coal particle, a considerable length of time would be required.

In order to illustrate the relatively large size of the coal particle as compared with the size of the oxygen molecules and the large number of these molecules that are required for the complete combustion of the coal particle, Mr. Shoudy compared the coal particle to a balloon and gave some very small dimension as the size of the oxygen molecules. I do not remember exactly the relative sizes that he gave. I have used a similar comparison on several occasions in order to illustrate the large size of the coal particle and the very large number of oxygen molecules that are required for its complete combustion. If we magnify the average coal particle, which is 1/500 of an inch in diameter, and the oxygen molecules one million times, the coal particle will be the size of a balloon about 250 feet in diameter and the oxygen molecules will be about the size of a poppy seed which is approximately 1/100 of an inch in diameter. At the furnace temperature the layer of air around the coal particle containing sufficient oxygen for its complete combustion forms a sphere about forty times the diameter of the coal particle itself. That is, the layer of the poppy seed representing the molecules of oxygen will form a sphere around the balloon about two miles in diameter.

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In this outer sphere the poppy seeds will be on an average, one quarter to one half of an inch apart, and will move rapidly in every direction due to their temperature. It is this motion that eventually brings them in contact with the balloon. Although this motion may be several miles per second, considerable time may be required before all the poppy seeds will make contact with the balloon, because they do not move in a continuous path, but collide with one another and frequently change their direction of motion. The free path between two collisions even on this enlarged scale may not be more than several inches or several feet at the most. The oxygen molecules collide not only with themselves but also with the molecules of nitrogen, and near the surface of the coal particle they collide also with the molecules of CO_2 and CO which have been formed by the oxygen molecules that have already made contact with the coal and are moving away. This means of bringing the oxygen molecules in contact with the coal particle is called natural diffusion. It is a comparatively slow process of bringing the oxygen molecules and the coal particle together. The oxygen molecules near the outer surface of the sphere of air surrounding the coal particle would have to travel nearly a mile and would require a comparatively long time to reach the coal particle because on their way they would make great many collisions with other oxygen molecules, nitrogen molecules and molecules of CO_2 and CO.

If in the case of our illustration instead of waiting for the poppy seeds to work their way to the surface of the balloon we would take the balloon and move it back and forth inside of this sphere of the air required for its combustion, the poppy seeds representing the oxygen molecules would come in contact with the balloon much faster. In a similar way if the coal particles are moved back and forth in the air, the oxygen molecules are brought in contact with its surface much quicker and the combustion is very rapid. We must bear in mind that the oxygen molecules cannot combine with the carbon any faster then they can be brought in contact with the surface of the coal particle. In other words, at the furnace temperature it is not a question how fast will oxygen unite with carbon but how rapidly can the oxygen be brought in contact with the coal particle. When the oxygen is brought in contact with the carbon it unites instantaneously. It is the rapidity of bringing oxygen and carbon together that determines the rate of combustion. Natural diffusion is a slow factor in bringing the oxygen and carbon together and resort must be made to intensive mixing in the furnace. It is the mixing that counts.

I have given the above illustration of the relative sizes of coal particle and the oxygen molecules in order to show that the process of combustion of powdered coal is not like the combustion of gas, although the flame resulting from the burning of powdered coal resembles somewhat the flame of burning gas. In the case of a gas fuel the size of the individual molecules are about the same size as the oxygen molecules, and in the case of hydrogen and carbon monoxide, one oxygen molecule will burn completely two molecules of these gases. In case of methane, two oxygen molecules burn completely one molecule of methane. Gases and air can be mixed before they are introduced into the

furnace and comparatively little mixing needs to be done during the process of combustion. On the other hand, when burning powdered coal most of the mixing must be done in the furnace while the process of combustion takes place because a very large number of oxygen molecules must be brought in contact with each particle of coal before these particles are completely burned.

When coal burns unaided by mixing, although there may be enough air for complete combustion surrounding the coal particles, the process of bringing the oxygen and carbon together is slow and the coal burns with a sluggish, smoky flame. When an accident occurs and a cloud of coal dust suspended in the air in the boiler room is ignited, the combustion is comparatively slow and smoky. The flame propagates with a slow enough speed so that those present, if they have good legs and space to run, can get away from the fire without being burned. Although such accidental fire is slow and smoky, it is hot enough to ignite any combustible material in its way.

I might cite an accident of this kind which occurred in a plant having five boilers fired with pulverized coal. We were running tests on one of these boilers and had two men on a platform about fifteen feet above the boiler room floor weighing pulverized coal. About thirty feet away from this coal weighing apparatus a man was repairing a pulverized coal feeder and accidentally spilled a small quantity of pulverized coal. This spilled coal formed a dust cloud which slowly spread towards the boiler on which we were running tests. This coal dust cloud was drawn through an air port in the furnace and the flame flashed back and ignited the dust cloud in the boiler room. The men weighing the coal saw it and had time to get away from the platform and out of the boiler room before the flame reached the place where they were working. The man who spilled the coal was only slightly burned because he too could get away from the flame. The dust cloud burned with a slow sluggish and smoky flame. The amount of coal burned in this accident did not exceed fifty pounds.

In the above accident the coal burned slow because oxygen was supplied to the surface of the coal particles by natural diffusion. If when we burn coal in furnaces we depended on natural diffusion to bring oxygen and carbon in contact the combustion would be slow and smoky. It is the mixing which makes combustion in furnaces rapid and produces high temperature.

If one wishes to make use of intensive mixing in the furnace, the furnace must be built with water cooled walls to withstand the impingement of the flames, because with turbulent mixing there is always impingement of flames against the walls of the furnace. If the furnace is lined with refractories the impingement of flames causes a rapid erosion of such refractories. Therefore, with refractory lined furnace the mixing must be limited in order to avoid rapid erosion of the furnace lining.

During the development of powdered coal as fuel for steam boilers, the furnaces were made of refractories and in order to avoid rapid erosion of the furnace walls, the furnaces were made very large to make complete combustion possible without intensive mixing, and also to keep the walls out of the flames. With modern water cooled furnace walls intensive mixing can be used because impingement of flames against the water cooled walls can be permitted without any danger of damage being done to the walls.

With intensive mixing the size of the furnace can be reduced and coal can be burned at higher rates of combustion. On some of the first powdered coal installations with refractory furnace walls the rate of combustion was limited to the maximum of less than two pounds of coal per cubic foot of combustion space per hour. With the water cooled furnace and more intense mixing the rate of combustion has now been increased to three pounds of coal per cubic foot of combustion space. The rate of combustion of three pounds of coal per cubic foot means the rate of heat liberation of about 36,000 BTU per cubic foot of combustion space per hour. We could go even higher than that if we were willing to accept higher losses from incomplete combustion. Under certain conditions a rate of heat liberation of 50,000 BTU may be found practical and economical, but in ordinary steam boiler practice a limit of 36,000 is high enough for all practical purposes.

We hear a great deal about short flame when burning powdered coal under certain conditions. Short flame is interpreted as good combustion. It is thought that the flame ceases because the combustion is complete. However, such may not be the case. The visible flame is the burning of the volatile matter in the coal. When the volatile matter is all burned the flame ceases, although practically all of the fixed carbon may still remain to be burned. The fixed carbon burns without visible flame. If there is any flame when fixed carbon is burned the flame is very different than the flame resulting from the burning of volatile matter. Usually it is difficult to observe any flame accompanying the combustion of fixed carbon. If the furnace is not large enough or if there is not sufficient mixing in the furnace, some of this fixed carbon may escape from the furnace unburned and will appear in the fly ash as particles of coke.

There may be a short visible flame in the furnace and still the amount of unburned carbon in the flue dust may be high. It is the unburned fixed carbon escaping from the furnace with the gases that constitutes the largest loss in incomplete combustion. Usually there is no unburned combustible gas escaping from the furnace. The gas burns easily and therefore burns completely in the furnace. The heavier particles of coal which may fall to the bottom of the furnace will also burn because there is enough oxygen at the bottom of the furnace and the temperature is high enough for the coal particles to burn completely.

Under certain conditions the unburned carbon in the flue dust may be as high as forty per cent of the dust. This is especially true of high fixed carbon eastern coals such as Pocahontas. We can take Pocahontas coal and give it all the advantage of hot refractory furance but if the mixing is not intensive enough some of the fixed carbon will escape unburned although the visible flame may be short. The flue dust may analyse as much as forty per cent combustible. Burning Pocahontas coal in powdered form is quite a problem. If we burn it

down to twenty per cent combustible in the flue dust we are doing quite well. However, a twenty per cent combustible in the flue dust is not such a great loss because Pocahontas coal has very low percentage of ash. There are some coals with the ash contents as low as five per cent. If such coal is burned with the resulting flue dust running twenty per cent combustible the loss does not exceed one per cent of the total heat in the coal. Of the five per cent of ash in the coal only about four per cent will go up with the gases as flue dust, the remainder of the ash in the coal drops to the bottom of the furnace. When the dust analyses twenty per cent combustible and eighty per cent ash, the eighty per cent of ash represents the four per cent of the original ash in the coal and the twenty per cent combustible in the flue dust represents one per cent of the original coal. Usually about one-fifth of the ash in the coal falls to the bottom and four-fifths flow out of the furnace with the gases.

With coals running higher in ash the same percentage of combustible in flue dust results in higher losses. Take for example coal containing twenty per cent ash, if the flue dust with such coal would run twenty per cent combustible and we assume that eighty per cent of the ash originally in the coal goes up as flue dust, then the eighty per cent ash in the flue dust represents sixteen per cent of the ash in the coal and the twenty per cent combustible represents four per cent of the original coal. In that case the incomplete combustion losses due to the presence of combustible in the flue dust amounts to about four per cent of the heat in the coal.

Some of the middle west coals run fifteen to twenty per cent in ash. High percentage of combustible in flue dust would represent a high heat loss from incomplete combustion. However, the middle west coals burn more easily than the high fixed carbon eastern coals such as Pocahontas coal. Whereas with Pocahontas coal it is difficult to reduce the combustible in the flue dust to twenty per cent, with the middle west coals it is comparatively easy to reduce the combustible in the flue dust to five per cent. In that case the losses due to incomplete combustion are about the same as they are with Pocahontas coal with comparatively high per centage of combustible in the flue dust. The easy burning of the western coal, however, is not due to high percentage of ash but to the low percentage of fixed carbon these coals contain, and to the character of the fixed carbon. The fixed carbon in the middle west coals burns much more easily than the fixed carbon in Pocahontas coal. The volatile matter is easy to burn in all kinds of coal. It is distilled off as gas which burns readily in a pulverized coal furnace.

The lignites are the coals most easily burned in powdered form. Even the fixed carbon burns readily. When burning lignite it is easy to reduce the combustible in the flue dust to one per cent. It seems that the fixed carbon in lignites combines readily with oxygen and is satisfied with less oxygen than the fixed carbon in eastern coals. Even with deficient oxygen supply it will find enough oxygen to burn to CO which is a combustible gas burning easily to CO_2 when it finds additional free oxygen in the furnace gases.

This easy combustibility of fixed carbon in lignite has been demonstrated by experiments made at the Bureau of Mines. In these experiments lignite was burned on a grate in a fuel bed 4½ inches thick. Air was passed through the grate and through the bed of lignite. Samples of gas were taken for every 1½ inch height above the grate. That is, the first sample was taken 1½ inches from the grate, the second sample 3 inches and the third sample 4½ inches from the grate. The air entering the fuel bed from below contained about 21 per cent oxygen. At the point of 1½ inches from the grate where the first sample was taken, the gases contained no oxygen, practically no CO_2 and over 30 per cent CO. The carbon may have burned first to CO_2 which in turn was reduced to CO by picking up more carbon, but whatever the sequence of the reaction was, the product of combustion 1½ inches from the grate was mostly CO. These products of combustion remain the same with rates of combustion varying up to fifty pounds of lignite per square foot of grate per hour. When eastern coals were burned under the same conditions the products of combustion contained 12 to 14 per cent CO_2 and only about 4 per cent of CO at a distance of 1½ inches from the grate. It seems that the fixed carbon in lignite has very strong affinity for oxygen and will take oxygen readily even from CO_2 reducing it to CO. When the fixed carbon is reduced to CO gas, the combustion of CO is readily completed even in the small concentration of the free oxygen such as exists in a pulverized coal furnace. Gas burns much more readily than solid combustible.

Finely pulverized coal will burn quicker than coarse coal. The small coal particles burn quicker because they need less oxygen for their complete combustion. That is, a smaller number of oxygen molecules need to be brought in contact with the small coal particle to burn it completely. However, in order to produce very finely pulverized coal we have to have larger mills or more mills because when coal is pulverized very finely the capacity of the mill is greatly reduced. We cannot get increased fineness without materially sacrificing the capacity of the mill. We can burn more fine coal in a given furnace than coarse coal or, a smaller furnace may be used when the coal is finer. It is a question whether we wish to have small furnace requiring fine coal and sufficiently larger mill to produce the fine coal or a large furnace capable of burning coarsely pulverized coal and a smaller mill producing large quantity of coarsely pulverized coal.

In the steam boiler practice the coal is not usually pulverized extremely fine. Coal running 65 per cent through 200 mesh and about 90 per cent through 100 mesh is considered of sufficient fineness to give good results. With small furnaces such as are found aboard ships, the fineness must be considerably higher. Some trials with powdered coal in Scotch Marine boilers indicate that the fineness must be such that at least 80 per cent of the coal passes through 200 mesh screen and 92 to 96 per cent through 100 mesh screen. If the coal is coarser a large percentage of the fixed carbon will pass out of the small furnace unburned. It is a question whether one wishes to invest his money in a large furnace or in a large mill.

Mr. Shoudy has shown you several types of mills. Some of these mills were of the high speed beater type, others of the medium speed roller or ball type, and still others of the slow speed ball type or the so-called tube mill. The last type of mill resembles the tumbler barrel used for cleaning small castings. Each of these types of mill has its advantages and disadvantages. The high speed beater type mill is well suited for the soft eastern bituminous coals. It has a high capacity and with these soft eastern coals the maintenance is low. When properly designed it gives reasonably good fineness. It is not suited for hard material such as anthracite or coke. Coke especially is very abrasive. When anthracite or coke is pulverized in the high speed beater type mill, the maintenance on the mill is very high. It is question whether the mill pulverizes the coal or the coal or coke pulverizes the mill. For that reason the high speed beater type mill is impractical for coke and anthracite coal.

The roller and ball type mills run at lower speed than the beater type mills and give good results with all bituminous coals. They produce coal of fairly uniform fineness and have very high capacity. Mills of this type can be built having a capacity up to 30 tons per hour. They are not well suited for the hard and abrasive material such as anthracite or coke because the wear on the pulverizing part is too high and the maintenance too costly.

The ball or tube type of mill is best adapted for hard abrasive material. The pulverizing part of the mill consists of small cast iron or steel balls which are comparatively inexpensive. Although these balls waste away rapidly, on account of their low cost, the maintenance on the mill is very low. The fineness of coal is usually very good and can be maintained over considerable range of capacity. However, the mills are very large for their output and at times noisy. All these types of mills can be used for either direct firing or the storage system. Usually the high speed beater type mill is used for direct firing, the roller and ball mill are more often used for the storage system. The ball or tube mill is used for both the storage system or the direct fired system.

Mr. Shoudy spoke about maximum per cent of moisture in coal that will give satisfactory results when the coal is burned in pulverized form. This percentage of moisture giving satisfactory results varies with different coals. With eastern coal good results are obtained with moisture of 3 to 4 per cent. With direct firing this moisture may be as high as 5 per cent. However, if the moisture exceeds 5 per ceint even with the direct firing method it is better to provide some means for supplying the mill with heated air so that some of the moisture can be dried out in the mill. If no heated air is supplied the capacity of the mill and the fineness of the coal is reduced and the resulting powdered coal does not mix well with air and burns spasmodically in the furnace. As a result of too wet coal the losses from incomplete combustion are high and the fire is erratic and may at times go out. This is particularly true of direct firing.

With the middle west coals such as the Illinois coal, moisture up to 8 or 10 per cent gives satisfactory results. With direct firing this moisture may be as high as 14 per cent particularly if heated air is supplied to the mill. With higher moisture than 14 per cent the feeding of coal to the mill becomes irregular and the fire is unsteady. A beater type mill is better suited to high moisture coal than the ball or tube type mill because drying and pulverizing can be better accomplished in the beater type high speed mill.

Lignites can be pulverized and burned in quite satisfactory manner with the moisture running as high as 30 per cent. There are two large plants in operation which have been burning Texas lignite nearly two years. The average moisture in lignite going to pulverizing mills is about 30 per cent. The moisture in pulverized lignite delivered to the furnaces is about 28 per cent. Very little trouble has been experienced due to this high percentage of moisture. Although this moisture is very high the coal appears quite dry because most of the moisture is on the inside of the coal or partly combined with it. It is the moisture on the surface of the coal particle which gives trouble in either pulverizing or burning the coal.

Mr. Shoudy also referred to the temperature of the air supplied to the mill for drying purposes. The question naturally arises how hot can the air be which is supplied to the mill for drying purposes? This temperature depends entirely on the moisture content of the coal, because the temperature of the air is rapidly lowered by the evaporation of the moisture. The higher the moisture in the coal the hotter can be the air supplied to the mill. With eastern coals running 4 to 5 per cent moisture a temperature of 250 degrees of air going to the mill is sufficient. The air may leave the mill lower than 150 degrees.

With middle west coals containing 10 to 14 per cent moisture no trouble should be experienced with the air going to the mill at a temperature of 350 degrees. With lignite containing 34 to 40 per cent moisture, I believe the temperature of the air supplied to the mill can be as high as 500 degrees. As long as there is moisture in the coal it's temperature will not rise to a danger point, because the moisture rapidly absorbs the heat by evaporation and greatly reduces the temperature of the air before the air gets very far through the mill.

Powdered Coal in Industrial Furnaces

The preceding discussion referred particularly to boiler furnaces where coal is burned to generate heat for making steam and the heat in the steam is changed into other form of energy such as electrical or mechanical energy. The more heat we can generate in the furnace the greater will be the output of the final form of energy. In the industrial plants, however, the coal is burned with another object. In such furnaces coal is burned to bring certain material to a desired temperature and keep it there for a predetermined period of time. The rate of heating the material may be either slow or fast. Usually it is slow. After the material is brought to the desired temperature it is held there so that the amount of coal that is necessary to burn merely supplies the heat which has been radiated from the furnace or been carried away by air or gas currents. Therefore, while with steam boilers we wish to liberate as much heat as possible and change it into another form of energy, in the industrial furnace we want to burn as little fuel as possible to hold the material at a desired tem-

perature or to heat it through a certain range of temperatures in a given period of time.

Another condition which we may wish to obtain in industrial furnaces and which is different from the boiler furnaces is that with certain materials we may wish to have the atmosphere in the furnace of reducing nature in order that the material heated may not become oxidized. In the boiler furnace the atmosphere is usually oxidizing. Maintaining a reducing atmosphere is more difficult than maintaining an oxidizing atmosphere, because by reducing the air supplied to the furance we may not get the combustion of the fixed carbon complete enough, and the coal particles may drop on the material to be heated in the form of coke dust and may produce undesirable condition, or may be carried out of the furnace with the gases.

In the boiler furnace we can resort to intensive mixing and if the furnace walls are water cooled we can tolerate considerable impingement of the flame against the walls. In the case of the industrial furnace it may not be desirable to have the flame impinging against the material to be heated so that we cannot employ similar intensive mixing. Without the intensive mixing the combustion is slow and much of the combustible may escape unburned either in gases or solid form. In many industrial furnaces the heat cannot be concentrated in one spot of the furnace but must be well diffused throughout the furnace volume so as to produce uniform heating. This condition may present some difficulties not found in the boiler furnaces.

The control of temperatures is more difficult with powdered coal than it is with gas. If we try to control the temperature by the air supply the oxygen shows preference for the gaseous combustible and combines with it leaving the fixed carbon unburned or ungasified. If there is any incomplete combustion the unburned combustible is in the form of fixed carbon and not in the form of gases. It is the combustible gas that produces reducing atmosphere. Although in places where the unburned carbon has been deposited the atmosphere may be sufficiently reducing, at the same time some distance away from this deposited carbon the atmosphere may be oxidizing.

For these reasons the application of powdered coal to industrial furnaces is more difficult and requires more thought in designing the furnace and burner and higher skill in operation than the boiler furnace. We have to study the desired condition as to the nature of the atmosphere, whether it should be reducing or oxidizing or whether the flame can be permitted to impinge against the material to be heated or be soft and the heat well diffused. We must study the desired shape of the furnace and the type of burner that will produce the desired shape and character of flame.

As a rule the manufacturer of powdered coal equipment does not have enough experience along the various specialized lines of heat application in industrial furnaces that would enable him to offer a definite design of coal burning equipment and be sure that the equipment and the design of the furnace would not have to be changed after they have been given a thorough trial. The amount of equipment the manufacturer can sell for the industrial powdered coal application is small and what little profit he may have figured on is generally lost by the time he has made a few changes in the equipment. Therefore, he is somewhat reluctant in pushing into this field. If powdered coal is to be successful in industrial applications the operator of the plant must assume at least half of the risk with the first installation. In most cases the operator of the plant has far greater experience with the process to which he wishes to apply powdered coal, and he should be able to give the manufacturer of the powdered coal equipment the help which he needs in selecting the proper type of equipment and help in designing the furnace and other special features of the installation which may be required for the successful application of powdered coal.

G. C. Emmons:* I made several notes during the presentation of Prof. Shoudy's valuable paper, but found that either Prof. Shoudy who read the paper or Mr. Kreisinger who so ably discussed it very thoroughly covered a number of these points before they finished.

For awhile it appeared that the industrial furnace field was going to be completely neglected and that only the boiler field was to receive attention, but Mr. Kreisinger saved the day in that respect by making some valuable comments relative to industrial furnaces.

One of the most important developments in recent years is the turbulent burner several forms of which Prof. Shoudy illustrated and described. For boiler firing, this type of burner has many advantages over the earlier or long flame type in which only a small portion of the air required for combustion is admitted at the burner. The majority of the air usually entered the furnace through a large number of small adjustable openings in the furnace wall. Since in this system of firing only a small amount of the air required for combustion enters with the coal, the coal burns slowly and with a long flame. This has the advantage of not developing nearly as high furnace temperatures as the turbulent burner and therefore permits the use of a furnace lining of uncooled high grade fire brick.

Higher rates of heat liberation necessitates the employment of air cooled walls, and still higher rates require water walls either supplementing the air cooled walls or replacing them.

The turbulent burner in which all the air for combustion is admitted at the burner inherently burns with a shorter flame and therefore develops a higher furnace temperature than the long flame burner. This necessitates the earlier use of air or water-cooled walls, or their combination, but permits employing a smaller combustion chamber volume. This feature is frequently of considerable advantage.

The greatest advantage of the turbulent burner, however, lies in the fact that since all air required for combustion enters the furnace at the burners, the entire quantity of air can be placed under control.

Five years ago we advocated that all air for combustion be supplied by forced draft and entered with the coal at the burners so as to place the total air under control. Development along this line has been materially accelerated by the further appreciation of the value of preheated air, the employment of which practically necessitates forced draft, thus permitting placing the entire air under control.

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*Fuel Engr., Republic Iron & Steel Co., Youngstown, O.

When you consider industrial furnaces for reheating steel, the employment of the turbulent burner which works out so satisfactorily in boiler practice, is out of the question for it always produces a temperature zone in the immediate vicinity of the burner. Such a condition produces what is termed a "rash heat" in which the surface of the steel is hot but the center of the steel is much below the surface temperature. Such a condition is obviously not desirable from a rolling standpoint.

To secure the best results in rolling steel, it is necessary that the steel be heated to the proper temperature throughout its entire cross-section and length. In order to accomplish this result it is necessary to maintain a long flame that will travel practically all the way down the furnace and out of the exit ports unless the furnace is of exceptional length. This permits the steel to far more gradually reach the final temperature and is accompanied by much more uniform temperature differences between the center of the steel and the surface temperatures. In a number of installations the gas temperature at the rear of the furnace is approximately 1400 deg., whereas the final steel temperature is 2200 to 2300 deg., and the gas or flame temperature at the discharge end of the furnace is two to three hundred (200 to 300 deg.) degrees higher than the final steel temperature, and when you have even the relatively low temperature differential of 300 deg., you approach this undesirable "rash heat" condition.

We have some furnaces on which the proper application of powdered coal would show a very handsome return on the investment. One such installation was our old rail mill which was formerly direct coal-fired. We placed powdered coal on this furnace with the result that we were able to save the service of two of our men; substitute slack coal at $3.62 per ton delivered, for lump coal at $4.96 per ton delivered; and reduce the fuel consumption 100 lbs. of coal per ton from 361 to 260 lbs., and some months to reduce the fuel consumption even lower, to 225 lbs. per ton. This installation showed over 100% earnings on the investment.

On some furnaces it is very questionable that powdered coal would be as satisfactory as other fuels. For example, some of our other furnaces fired with producer gas have such low fuel consumption that it is probable that powdered coal could not be substituted to advantage. It is therefore essential that each case be studied carefully before a conclusion can be reached as to the advisability of substituting powdered coal.

W. B. Chapman*: The comparison that has been made between the size of a molecule of gas an the average size of a particle of pulverized coal (1/200 inch) showing a relative difference equal to the difference between a poppy seed and a sphere 500 feet in diameter, indicates the enormous handicap that is imposed upon the use of pulverized coal as compared with gas.

If the molecule of gas has an advantage in size of one to many million, we as engineers would do well to look more carefully into the possibilities of artificial gas. Do not the great strides made with pulverized coal during the past ten years indicate still greater strides that might be made with artificial gas?

The only advantage of pulverized coal is that "it burns like gas." It has merit—a lot of merit—because it is a fairly good "imitation gas." But can the imitation be better than the real thing? The only reason for using an imitation of anything is because it is cheaper. In the past pulverized coal has been cheaper than artificial gas, but the situation is changing rapidly. I believe that if one-tenth of the effort that has been expended upon pulverized coal during the past ten years had been expended upon producer gas, it would be cheaper than pulverized coal and the problem of the efficient generation and application of producer gas for boiler firing would have been solved.

Formerly, if all overhead expenses were included, it cost well over $1.00 per ton of coal gasified to make producer gas. This figure has now been reduced to about 50c a ton, which compares favorably with the cost of handling and preparing pulverized coal, including all overhead expenses. Producer gas is therefore on a substantially equal cost basis with pulverized coal and in addition is free from the disadvantages arising from ash content.

A gas producer to be applicable to boiler heating should have a capacity of not less than 50 lbs. of coal per square foot of fire-bed. Much higher than this amount has been attained during the past two years by several different manufacturers of producers. However, there are no producers on the market today that are suitable for boiler heating. Such a producer should be of the underfeed or side-feed type and should be provided with very complete mechanical agitation driven from either the side or beneath the firebed so as to eliminate the producer top altogether. It will then be possible to locate a mechanical producer directly under a boiler—a thing that as yet has never been done.

Small hand operated gas producers are now being used directly under boilers with remarkably good results, that compare favorably with large central power plants. The CO_2 in the stack gases average over 17%.

This meeting is supposed to stress the use of pulverized coal for heating industrial furnaces. This field is more complicated than the heating of boilers. Every little furnace has a problem all its own when heated with pulverized coal and by the time the problem is solved and the operators are educated to handle their new equipment the profit to the manufacturer of the equipment has all been dissipated. Hence the industrial furnace field for pulverized coal has not as yet been profitable. On the other hand, the heating of industrial furnaces is an easier field for producer gas than boiler heating.

It does not seem to me that as engineers we can look to pulverized coal as possessing outstanding possibilities for industrial furnace heating. The handicap of the ash content of pulverized coal and the lack of molecular fineness must be largely overcome before this field can be made attractive. The development of the mechanical gas producer seems to be free of such handicaps and to possess greater possibilities.

*Chapman-Stein Furnace Co., Mt. Vernon, Ohio.

Soaking Pit Covers

By LOUIS ELLMAN*

Any design of soaking pit cover must include certain essential features. They are:

1. Provisions for a satisfactory seal between the top of the pit walls and the cover.

2. A substantial frame to withstand the jarring, bumping and other shocks due to usual handling.

3. Refractory lining for the inside of the frame, disposed in such a manner as to form a cover over the pit and protecting the frame from escaping hot gases and flames.

The conventional soaking pit cover is made of either a cast steel or cast iron frame lined with either a crown or arch of standard fire brick shapes. The frame is usually made excessively heavy, first because each side acts as a skew back for the refractory arch, and secondly, to provide sufficient material in case the metal parts of the cover are attacked by the escaping hot gases and flames.

This type of cover is more readily attacked by the gases and flames because there is always an opening between the top of the pit walls and the underside of the pit cover along the skew back line.

Repairs to this type of cover are expensive because the frame is made either in one piece or, as in some cases, in four pieces. When any part of the frame is burned an entire new side of frame must be provided or considerable welding done.

The fire brick arch cannot readily be repaired. It must be entirely replaced when burned out or broken down due to excessive jarring or bumping.

A soaking pit cover overcoming the several objections inherent in the conventional type of pit cover is illustrated in Figs. 1, 2 and 3. This design of pit cover embodies the following features:

1. A substantial structural steel frame providing a maximum strength for a minimum weight.

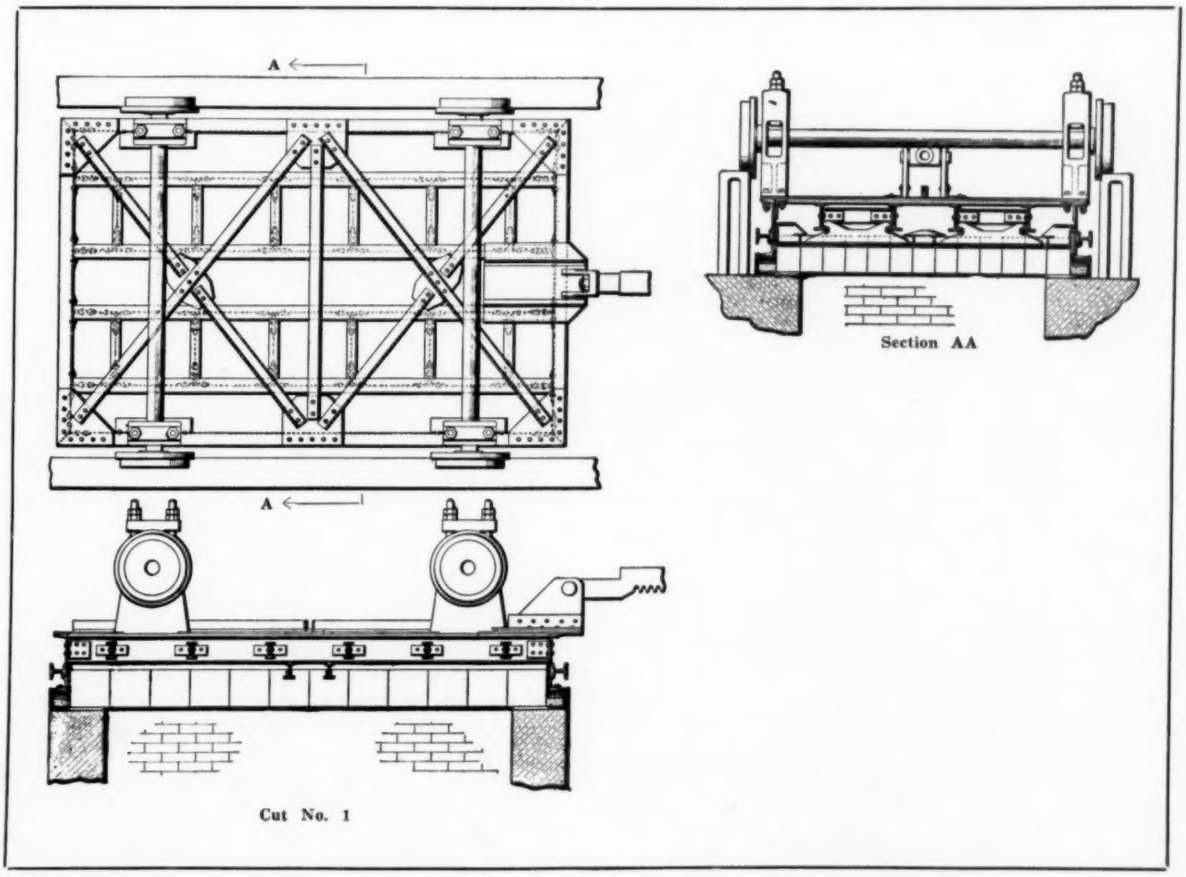
2. Cast iron shoes protecting the structural steel frame made in short lengths so that if any repairs are required due to metal parts burning out they can readily be replaced at a minimum of expense.

3-A. A suspended fire brick tile lining providing the best possible seal on the pit walls and designed so that repairs can be made to the fire brick lining in sections never necessitating the relining of the entire pit cover.

3-B. The use of suspended tile minimizes the possibility of the refractory portion of the cover failing due to jarring or bumping.

There are a number of soaking pit covers of this type in use in several large steel plants. Every installation has proven successful.

*Vice President, M. H. Detrick Co., Pittsburgh, Pa.



Cut No. 1

The Economic Value of Safety Work*

By L. H. BURNETT†

WHEN our good friend Secretary Waters asked me to address this Congress on the subject of "The Economic Value of Accident Prevention," while I thoroughly appreciated the honor, I accepted the invitation with some reluctance, as I felt incapable of rendering complete justice to the subject. All my early training and most of my thoughts with reference to Safety have been along humanitarian and social lines rather than from an economic standpoint.

Twenty years ago Judge Gary, Chairman of the United States Steel Corporation, called together the casualty managers of the larger subsidiary companies of that organization. These casualty managers were men who were in daily contact with all the loss, the suffering and the sorrow caused by industrial accidents. They were thoroughly familiar, not only with the direct results of industrial accidents but also the indirect results such as the loss of life and limb, loss of earning power of the bread winner, the widow and children left without adequate support, to ultimately become charges upon society in general. The only thought at that meeting was that too many men were being hurt and killed in industry, and that ways and means must be found for preventing, or at least decreasing, the number of such accidents. It was well understood that such a campaign would be costly and expensive, but, whatever, the cost, it was deterimned that such accidents should be prevented in so far as possible.

And this has been the spirit of the Safety campaign from its inception. It has been firmly based upon the humanitarian motive. There was no thought of economic gain or advantage until long after Safety had been sold to the thoughtful employers and employes of this country. If our plea for safety had been based upon economic grounds it might have fallen upon deaf ears, it might not have received the hearty support of the press, but based upon humanitarian and sentimental reasons it naturally attracted the attention and support of the public in general.

It is difficult, if not impossible, to completely separate the humanitarian from the economic side of Safety work. The two go hand in hand. The underlying motive has been and always will be the humanitarian side, but experience has taught us that many economic advantages inevitably flow from intensive safety work. Such advantages being so extensive as to make Safety work highly desirable from a purely dollar and cents standpoint.

Considered solely from an economic standpoint, the advantages of Safety work or accident prevention in industry may be divided into two general classes:

(1) direct and (2) indirect.

The direct advantages are those which are perfectly obvious and, while it is not my purpose to burden you with figures, the savings can be given in dollars and cents. Every accident prevented means a saving of just so much in compensation and necessary medical care and attention. Whether an employer carries compensation insurance, State insurance, or assumes his own risk the benefits derived from the actual prevention of accidents are substantial and immediate.

The experience of a large foundry company with an average working force of 500 men affords an excellent example of money savings due entirely to intensive safety work.

In 1925 time lost due to accidents was 62½ days per 100 tons of castings shipped; the cost of accidents being 66 cents out of every $100 payroll.

In 1926 the lost time was 30 days per 100 tons of castings shipped; the accident cost being 10 cents per $100 of payroll.

In 1927 they conducted an intensive safety campaign, and as a result the time lost was half-day per 100 tons of castings shipped; costing one cent per $100 of payroll. The actual reduction in costs, due to accident prevention is indicated by the following figures:

1925—cost of accidents was	$7,033.03
1926—cost of accidents was	3,132.88
1927—cost of accidents was	121.50

A public utility employing an average force of 1,500 men, by reducing accidents, cut their compensation costs from 30 cents per $100 of payroll in 1926 to 6½ cents in 1927.

A large steel works employing 5,000 men cut compensation costs from $24,378.89 in 1926 to $10,407.45 in 1927; showing a saving of $13,971.44. These figures do not include savings due to decrease of medical and hospital service.

One of our largest car and foundry companies spent $1,000,000 for accident prevention in 14 years and saved $2,700,000.

It is said that the United States Steel Corporation spent $9,763,063 in safety work in 10 years and showed an actual saving of $14,609,920.

In view of these records there can be no doubt that accident prevention work does pay from a purely economic standpoint, and let us not forget that the figures above given show only the direct savings in compensation and do not reflect the many indirect benefits not only to the employes but to the public at large.

When intensive safety work was first begun there was a general feeling among industrial leaders that such work would seriously interfere with and hamper production, and it was only after many years that safety engineers were able to demonstrate that accident prevention work, far from being a hindrance to full production, was and is an actual aid. This is due to the fact that the safety campaign has long since graduated from mere safeguarding of dangerous machinery to the position of an ever increasing and active educational force in industry. It demands the thought and attention of every man in the organization from the highest to the lowest. A safe plant must be a clean and

*Presented before Pennsylvania Safety Congress, March 21, 1928.

†Vice President, Carnegie Steel Co., Pittsburgh, Pa.

orderly plant and such cleanliness and orderliness have been found to be necessary for good production.

A safe plant must be well lighted and all dark and dangerous places eliminated. It has been demonstrated time after time that good lighting is an actual aid, in fact it is absolutely essential to good production.

Absence of workers, due to injuries, causes changes in personnel requiring the hiring and training of new men. The bare cost of hiring a new man will run from $30 to 80. Such accidents disrupt the morale of an organization. Accident prevention conserves the time, energy and physical fitness of employes. It produces a more stable and contented working force and "A stable, contented and highly efficient working force is the fondest dream of every manager, every department head and every foreman."

A recent survey of 14,000 industries employing 2½ million workers, comparing results of 1922 with 1925, shows 12 per cent increase in production and 18 per cent decrease in accidents.

Blast Furnaces producing pig iron in the last ten years show an increase in production of 60 per cent and a 50 per cent decrease in accidents.

Today accident prevention is just as much a business proposition as production. In fact no plant can be truthfully said to be on a sound business basis until Safety is as much a matter of daily consideration and practice as quantity and quality of production.

Time will not permit more than a mere mention of some of the economic factors in accident prevention. However, it is true that the average mill worker today can buy life insurance at the same rate of premium as the office worker or other preferred risk. Before we had accident prevention, he was compelled to pay a much higher rate.

In fact, it is undoubtedly true today that whether we look at accident prevention from the humanitarian standpoint or from the economic side, we can safely say that it pays; that it is worth while, and that it is worth much more than the effort and energy expended or the dollars and cents invested.

The results which have been attained are due to the hearty co-operation and support of the State, the employers and employes, and to the constantly growing campaign of safety education, which is spreading from our railroads and industrial plants and reaching into our homes, our schools and our churches. Pennsylvania has accomplished much, and the Department of Labor and Industry deserves the highest praise for the hearty co-operation and assistance which it has rendered to the Safety movement and the campaign of education which it has fostered.

The campaign of accident prevention is founded upon reason and common sense. It will go on, gathering power and momentum as it goes, until the unnecessary sacrifice of life and limb has been abolished. We have learned that it pays, but let us not forget that the highest aim of safety work must always be the prevention of accidental injury and death and the pain and sorrow which inevitably follow. As one writer has put it "And the end is that the workman shall live to enjoy the fruits of his labor; that his mother shall have the comfort of his arms in her age; that his wife shall not be untimely a widow; that his children shall have a father and that cripples and helpless wrecks, who were once strong men, shall not longer be a by-product of industry."

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*Rules Governing the Operation of High Tension System**

1. The object of these rules is the prevention of accidents. If, in the judgment of anyone whose duty it is to enforce a rule, such rule is impracticable, or fails to provide proper protection, he shall immediately bring it to the attention of those in authority.
2. All potentials over 275 volts shall be classed as high tension.
3. A circuit shall consist of all the high tension electrical conductors that may be cut off from the Power House or from a sub-station by the operation of a single switch, or by two switches in the case of a double system. In case, however, a circuit runs from the Power House to one or more sub-stations, it may be necessary to cut it off at the Power House and at each sub-station to completely deaden it.
4. No work shall be done on live high tension circuits or apparatus except in the following cases:

   (a) Changing fuses on static transformers, lightning arresters, etc. Wooden tongs are provided for this purpose and must always be used. The man doing this work must be thoroughly instructed as to the safe way of doing it and must be accompanied by an English-speaking helper except when fuses are located in the Pipe Mill Sub-station, Continuous Skelp Mill Motor House, Universal Mill, Motor House, or Pump House.

   (b) Operating disconnecting switches. Special hooks with wooden handles have been provided for this purpose and must be used. This work must be done only by men thoroughly instructed as to the safe way of doing it. Any man doing this work must be accompanied by an English-speaking helper except when switches are located in Pipe Mill Sub-station, Continuous Skelp Mill Motor House, Universal Mill Motor House, or Pump House.

*Rules in use at one of the prominent eastern steel plants.

(c) Making high tension tests. Test leads must be insulated at points where they will be handled when alive to withstand at least four times the maximum voltage used in testing. Only persons authorized by Superintendent of Electrical Department or his assistant, shall make high tension tests.

5. Provision shall be made for grounding and short-circuiting all high tension circuits at their terminals or disconnecting points. In attaching ground and short-circuiting device, ground end shall be attached first and line ends shall then be attached by use of insulated poles or tongs.

6. (a) The man in charge of Pipe Mill Sub-station shall be known as Sub-station attendant.
The man in charge of Continuous Skelp Mill Motor House shall be known as Motor House attendant.
The man in charge of Universal Mill Motor House shall be known as Universal Mill attendant.
The man in charge of Pump House shall be known as Pump House attendant.

(b) All of the above men must be thoroughly conversant with the rules governing the operation of the high tension system.

(c) The **Sub-station attendant** shall have full charge of all incoming and outgoing circuits at Pipe Mill Sub-station and high tension equipment in Pipe Mill Sub-station.

(d) **The Motor House attendant** shall have full charge of all incoming and outgoing circuits at Motor House and of all high tension equipment, except circuits to or from Pipe Mill Sub-station in Skelp Mill Sub-station in Skelp Mill Motor House. Circuit breakers on lines connecting with Pipe Mill Sub-station shall be operated only under direction of Sub-station attendant.

(e) **The Universal Mill attendant** shall have full charge of all high tension equipment in Universal Mill Motor House.

(f) **The Pump House attendant** shall have full charge of all high tension equipment in Pump House. He shall, however, follow instructions of Motor House attendant when requested to change from one line to the other.

(g) No attendant shall leave his station without having been relieved except by order of the Superintendent of Electrical Department or his assistant, General Foreman or his assistant, in charge of the Department in which his station is located.

(h) Pipe Mill Sub-station, Continuous Skelp Mill Motor House, and Pump House will each have two incoming lines, one from an Industrial Co. and one from a Central Station. It is impossible to operate these lines in parallel; and under no conditions must both lines be thrown on the bus at the same time.

(i) No attendant shall permit work to be done on a circuit or apparatus under his charge without first having received a request for a permit to do such work.

(j) When an attendant is asked for a permit to do work on a circuit or apparatus, under his charge, he shall proceed as follows:

(1) Enter the request on High Tension Order Form No. .....

(2) Read the request aloud to person making it.

(3) Trip the circuit breakers connected to the line or apparatus upon which work is to be done; and, in case of incoming line, have circuit breakers at the other end of line tripped.

(4) Open disconnecting switches.

(5) Apply safety lock to circuit breaker.

(6) Fill out and attach hold card to circuit breaker or switch.

(7) Apply ground and short circuit to circuit or apparatus upon which work is to be done.

(8) If work is to be done on an incoming line from the Industrial Co., he shall request load dispatcher at Industrial Co. to open circuit and apply ground at the Industrial Co.'s end of circuit, and shall satisfy himself that this has been done. If work is to be done on the Central Station line, sub-station attendant shall open remote control circuit breaker at outdoor transformer station, and instruct person requesting permit to open disconnects and apply ground and short circuit at outdoor transformer station, and shall satisfy himself that this has been done.

(9) Take any other steps that, in his judgment may be necessary for the safeguarding of dead apparatus.

(10) Notify person making request that apparatus is dead and that he may proceed with his work.

(11) In case more than one gang desires to work on a circuit or apparatus at the same time and the attendant has proceeded as above for the first gang, he will be required only to make out additional high tension order and fill out and attach additional hold cards for each succeeding gang; but need not apply other safety padlocks to the oil switches.

(12) When attendant is notified by the man in charge of the work or by General Foreman or his assistant under whom that man works, that his work is done, he shall remove the corresponding hold card and check it against the order. If but one gang has been working on a circuit or apparatus, he shall then remove the safety padlock from the switches and may put the circuit or apparatus into service when required. If more than one gang is working on a circuit or apparatus, he shall not remove safety locks until he has received notice from man in charge of each gang that has been working.

(13) All high tension orders shall be made out in triplicate and held by the attendant until the circuit or apparatus is re-

(Continued on page 209)

A. I. & S. E. E. JUNIOR DIVISION

(Devoted to practical problems of electrical department employees in the Iron and Steel Industry)

The steady increase in the application of electric power to the iron and steel industry has resulted in the necessity of building up electrical department organizations capable of properly maintaining these installations. The amount of capital invested warrants employing highly trained men for this work. Experience has also shown some of the larger companies that more satisfactory results are obtained where new installations are planned and installed by their own engineering organization, instead of employing some one not so familiar with the conditions under which the equipment must operate. This plan when worked in co-operation with the manufacturer of electrical equipment has in many cases resulted in what might be considered as ideal installations, both from the standpoint of operation and installation costs.

The gradual increase in steel making and rolling capacity will eventually result in complete engineering organizations in many plants in which such an organization is not warranted at the present time. All of this is going to result in an increased demand for properly trained men to make up these organizations.

While it is true that a certain number of technically trained men are necessary in a complete organization, as mentioned above, it appears that the opportunities which involve the greatest number of men will be positions which can be very satisfactorily filled by men who have taken advantage of opportunities to learn while working which opportunities are now available to almost everyone. As a typical illustration; in a plant employing approximately five hundred men doing electrical work in one form or another probably ten technical graduates is all that will be found in that organization and probably 50% of these are men just out of school, working for experience and at a rate of pay less than the earnings of the average mill electrician.

Developments in the application of electric power, light and heat in the steel industry at the present time are becoming more and more specialized necessitating that the men actually doing the maintenance work on this equipment thoroughly understand the application. This necessitates that men so employed take advantage of every opportunity to increase their understandings of the equipment in question. For without this knowledge men who have not endeavored to keep up to date in every line will certainly be left behind in the development of complete plant organizations, which must be built up as the plant becomes larger and larger.

Realizing this the Association of Iron and Steel Electrical Engineers feels that this organization is the most logical one to assist in training the men for these positions. With this in mind this Association has inaugurated what is to be known as a Junior Membership, which membership will entitle a man to the monthly copies of the Iron and Steel Engineer. Furthermore, it is proposed to cover, through the medium of the Iron and Steel Engineer, a continuous series of educational articles covering such fundamental principles as are necessary together with the direct application problems which confront the steel plant electrician every day. All of this will be in additon to the field which the magazine now covers, much of which in the past has been very good information could it have reached the hands of the average maintenance man in the field.

As the educational program will begin with the article on "Direct Current Motor Control" in this, our May number, it would be well for all those who contemplate becoming Junior Members, to begin their connection from the start of the program. Membership blanks for Junior Membership have been placed in the mails and the returns already received insure the success of this undertaking. If you have not already filled in your application, it would be well for you to give it your immediate thought NOW.

Article One—
For Electrical Department Employees

Direct Current Motor Control

Starting of D.C. Motors

IF full voltage is applied directly to a D.C. motor there will be an abnormal inrush of current due to the low resistance of the armature winding. For this reason a resistance is placed in series with the armature of a D.C. motor when starting. As the motor comes up to speed a generator action takes place producing a counter voltage in such a direction as to oppose the applied voltage. As this action takes place and the motor reaches its rated speed the voltage tending to force current through the armature is the difference between the counter voltage and the applied voltage. At rated speed this difference or net voltage is quite low and not sufficient to force any injurious amount of current through the armature winding and the resistance is no longer needed.

D.C. Starters and Controllers

Direct current motor starters are merely devices for applying power to the motor and bringing it up to rated speed whenever required. Motor controllers serve the same purpose but in addition

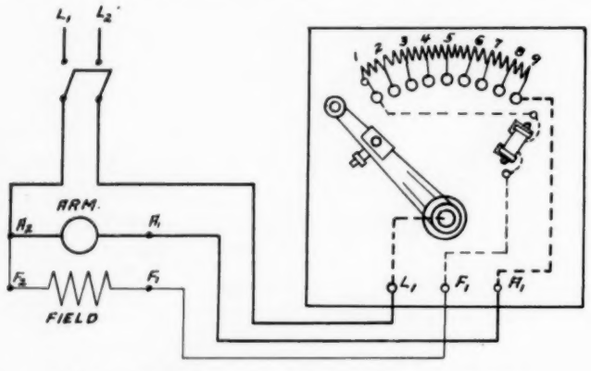


FIG. 1. DIAGRAM OF A FACE-PLATE STARTER

provide a means of varying the speed, reversing or otherwise governing the performance of the motor.

Classes of Starters and Controllers

Starters and controllers may be divided into two classes depending on the method of control that is, direct or manual, and remote. The direct or manual types are those carrying the motor circuits and handled directly by the operator. The remote types are those in which the apparatus carrying the motor circuits are not handled by the operator but is controlled by master switches, push buttons or other devices connected to pilot circuits. In some special cases remote control is operated by compressed air.

Manual Starters and Controllers

There is such a wide variety of manual starters and controllers on the market that it will be impossible to cover them in any other than a general way. However, they can be divided into three general classes depending upon their construction, namely multiple switch, face plate and drum type.

Multiple Switch Starter

The multiple switch starter consists of a number of switches for cutting out the accelerating resistance by steps. The switches are so latched in by a magnet catch that when the power fails or the main switch is opened the switches automatically drop open or to the off position.

Face Plate Starters

One of the most common types of starters for small motors is the face plate starter, a diagram of which is shown in Fig. 1. This consists of a box of self contained resistance with numerous taps coming up to segments mounted on an insulating plate and a lever carrying contacts which slide over the segments. The lever is ordinarily arranged with a holding coil for keeping it in the running position and a spring to return it to the off position when the holding coil releases due to voltage failure or opening of the switch.

Face plate starters are sometimes used for speed regulation by armature resistance. Such starters have heavier resistance and are arranged so that the lever can be held on any contact thereby keeping a certain amount of resistance in the armature circuit.

Face plate starters are also made with combination starting resistance and a field rheostat for variable speed shunt motors. This consists of two resistance elements and an auxiliary field rheostat arm. The motor is brought up to speed with full field and the starting arm is held by a voltage coil. The field rheostat arm may then be brought back to increase the speed by cutting resistance in the shunt field circuit.

Face Plate Controllers

Face plate controllers are quite common in older installations of series or compound wound motors which are subject to much reversing and plugging. Figure 2 gives a clear idea of the common face plate controller. This type of controller has been used quite extensively because of its simplicity, ruggedness, ease and speed of operation. From the standpoint of safety and protective features this controller is very undesirable as practically all contacts and connections are exposed.

Drum Type Controllers

A very satisfactory type of manual controller for series or compound motors requiring much manipulation is the drum type controller. This type of controller is most commonly used for simple reversing drives such as hoist motors. It consists primarily of a cylinder having numerous conducting segments on the surface and one or more sets of flexible contact fingers. The drum segments may be connected to or insulated from one another as required. The contact fingers are generally insulated from each other and furnish the connections for lines, armature, field and resistance leads. In the plain reversing controller Fig. 3 the drum segments are so arranged that by turning the cylinder in the forward direction they will complete the necessary circuits through the contact fingers to apply power to the motor and cut out the accelerating resistance gradually by going from one segment to another. By turning the cylinder in the reverse direction a different set of segments mounted

on the same cylinder engage with other fingers to reverse the field or armature connections thereby reversing the direction of rotation. The motor is accelerated the same as before but with a different set of segments engaging with the same fingers as for forward rotation. The operating lever is provided with a star wheel and pawl for distinguishing the various steps as well as stops for limiting the cylinder rotation in both directions. By rearranging the segment or by the use of additional fingers and segments a different sequence of connections can be obtained and dynamic braking or slowdown resistances employed for hoist motor operation.

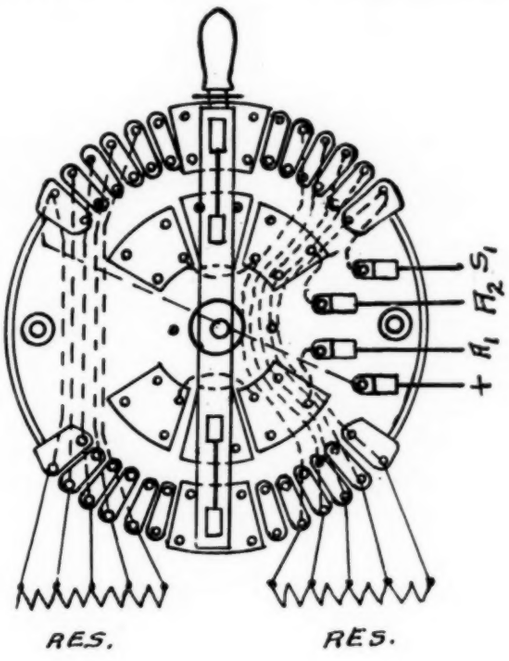


FIG. 2 FACE PLATE CONTROLLER

Principles of Remote Control

Remotely operated starters and controllers most mommonly employ solenoids or magnet coils for closing contacts, actuating levers or performing any of the operations required of an operator in the use of manual control. Solenoid action and magnet action differ in that a solenoid coil is wound on a hollow non-magnetic spool so that the flux set up by the coil will exert a force inside the hollow spool while a magnet coil is wound or placed over a soft iron core such that the flux set up by the coil will exert a force through the iron core or magnetic circuit.

Solenoid and magnetic principles are embodied in the design of unit type contactors and relays which form the basis of magnetic starters and controllers. The solenoid principle is used quite extensively in the design of relays while the magnetic principle is used extensively in the design of the "clapper type" contactor.

Clapper Type Contactors

The clapper type contactor which is most commonly used for the handling of motor circuits consists primarily of an iron frame, operating coil, movable arm carrying a contact and a stationary contact. Such contactors are made in numerous designs but might be divided into two general classes namely series contactors and shunt contactors. The series contactor has an operating coil wound of heavy copper for use in series with motor circuits. Shunt contactors have operating coils wound of fine wire for operation usually on line voltages.

Magnetic Controllers

Magnetic controllers consist of an assembly of contactors and relays inter-connected in such a way as to perform the desired control functions. One of the fundamental requirements of all controllers is some method of providing satisfactory acceleration for the motor. Magnetic controllers may be divided into the two general classes of current limit and time limit controllers, depending upon the principles used in governing the acceleration of the motor. In current limit acceleration the various steps of resistance are cut out only as the motor current drops to some predetermined safe value. In time limit acceleration the various steps of resistance are cut out at definite time intervals, regardless of the motor current.

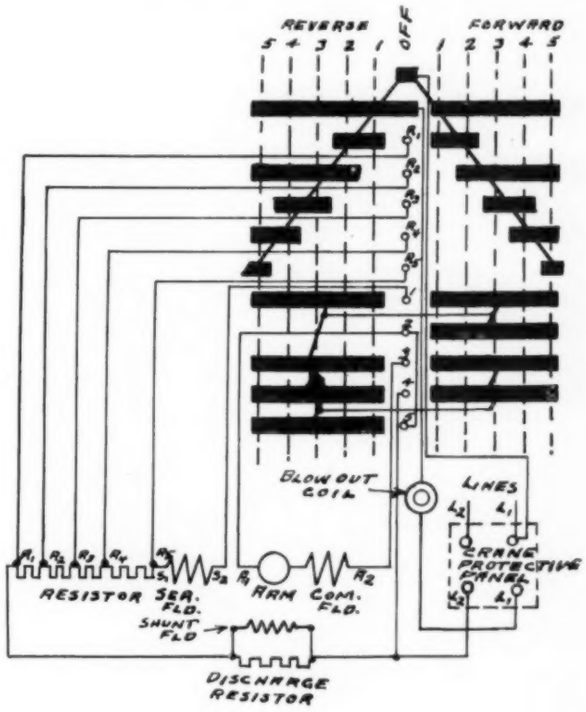


FIG. 3. CONNECTION DIAGRAM FOR SIMPLE REVERSING DRUM CONTROLLER

Controllers using current limit acceleration may still be divided into classes according to the method by which such acceleration is obtained, namely counter voltage, series lockout, series relay and voltage drop.

Counter Voltage Control

Figure 4 illustrates the principle of the counter voltage scheme of control. The accelerating con-

tactors are provided with shunt operating coils which operate from the counter voltage generated by the armature as it comes up to speed. The contactor coils may be connected directly across the armature or across the armature and sections of the starting resistor as shown. If they are hooked across the armature the coils and air gaps must be adjusted for different values of voltage if they are to close in sequence as the armature comes up to speed. By connecting them as shown in the diagram the voltage drop across the resistor sections provides the various voltages and interlocks or voltage adjustments on the contactors are not needed.

Series Lockout Control

The series lockout scheme of control employs accelerating contactors with series wound operating coils and so designed that they will lockout or hold open on high values of current and close when the current drops to a predetermined value. Single and double coil contactors having this characteristic are in general use.

In the single coil lockout contactor this action is obtained by using two magnetic circuits for the flux set up by the coil. The flux in the first or closing circuit tends to close the contactor while that in the second orlockout circuit tends to hold it open. For high values of current the first or closing circuit becomes saturated and considerable flux passes through the lockout circuit holding the contactor open. As the current decreases the flux in the

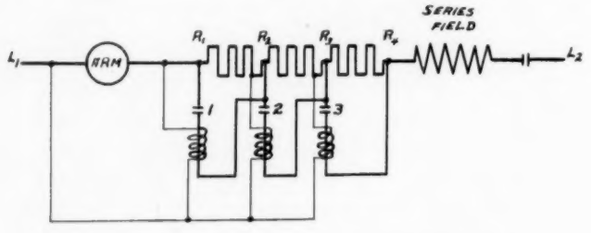


FIG. 4. PRINCIPLES OF COUNTER-VOLTAGE ACCELERATION

lockout circuit dies out and the contactor closes due to the flux in the first circuit. An adjustable air gap in the lockout circuit prevents any great amount of flux from passing through this circuit at low values of current and provide sa suitable means of adjustment.

The double coil type of contactor is provided with a series closing coil and a series lockout coil. The magnetic circuits are so designed that the closing circuit reaches saturation and exerts a strong pull on relatively low values of current while the lockout circuit does not reach saturation and exerts a stronger pull with heavier currents. With light currents the pull of the closing coil is greatest and the contactor will close, but with heavy currents the pull of the lockout coil is the greatest and the contactor holds open until the current drops.

Figure 5 shows a diagram of the connections of a simple reversing controller using series accelerating contactors. The directional contactor 1R &2R, and 1F & 2F are shunt contactors operated by the master or control switch. When one set of the directional contactor is closed the current flows through the motor, the series resistor and the series coil of contactor 1. The inrush of current to the motor at rest is high and contactor 1 locks out until the motor starts rotating and the current drops. When the current drops, contactor 1 closes, short circuiting the first section of resistance and allowing another inrush of current. As the motor continues to gain speed the current drops and contactor 2 closes, short circuiting the second step of resistance. This process continues until the motor is up to speed and all accelerating resistance is shorted out.

Series Relay Control

The series relay scheme of control employs shunt accelerating contactors whose coils are energized through the closing of contacts of series relays. The series relays operate much in the same manner as the series lockout contactors although their contacts only carry the control circuits which complete the circuits for the operating coils of the shunt contactors. Series relays which do not have the lockout principle have the contacts normally held open by a spring or lever until the series coil is energized. When the series coil is energized the spring or lever arrangement is released by the directional contactor or accelerating contactor which has preceded it and the contacts of the relay are held open by the strength of the current. When the current drops to a predetermined value the relay armature closes completing the circuit for the operating coil of the next accelerator. This continues until all accelerators have closed. When the

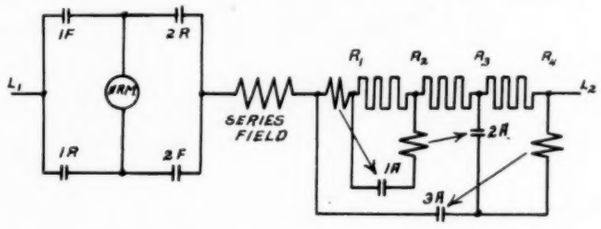


FIG. 5 PRINCIPLES OF SERIES-LOCKOUT CONTROL

motor is shut off the contactors drop out and mechanically reset the series relays.

Voltage Drop Control

The voltage drop system employs shunt accelerating contactors and relays with shunt coils that operate from the voltage drop across sections of the starting resistor. The voltage drop across sections of the starting resistor is proportional to the current flowing through it, therefore, this system of control is essentially a current limit control.

The voltage drop relay consists of two shunt coils and a single armature with normally closed contacts. Fig. 6 shows the application of the voltage drop relay. When the line switch is closed the lower or assisting coils of the relays are energized and the relay armature picks up, opening the contacts. When the starting or directional contactors close the assisting coil of the first accelerating relay is short circuited. The armature is now held up by the upper or calibrated relay coil which is energized by the voltage drop across the first section of resistor. As the motor comes up to speed the current through the resistor decreases and the voltage drop becomes less. When the voltage drop falls to a predetermined value according to the relay setting the armature releases closing the contacts for the first accelerating contactor. The same action

takes place in the remaining relays whose armatures are held open by the drop across other sections of the resistor.

Principles of Time Limit Control

In the oldest and most common forms of time limit starters and controllers the timing of the accelerators is obtained by the use of auxiliary motors, solenoids or dash pots. However, there are a number of time limit controllers of comparatively

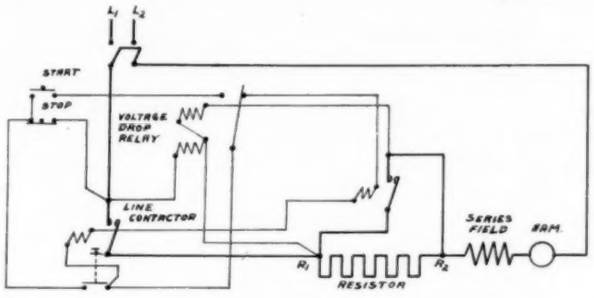
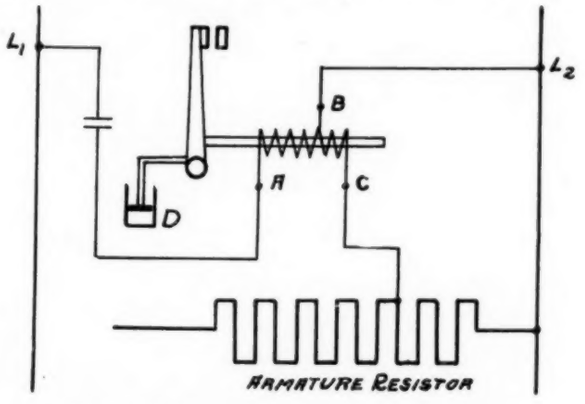


FIG. 6. PRINCIPLE OF VOLTAGE DROP CONTROL

recent design in which the timing is obtained magnetically. Controllers which function through the operation of an auxiliary or pilot motor are confined to more or less special applications and are not in common use. Dashpot timing is used quite extensively in starters for small motors and to a certain extent in controllers for larger motors. Controllers using magnetic time limit acceleration are in common use on crane motors, auxiliary drives in steel mills and other industrial applications of a similar nature.

Dashpots consist merely of movable pistons operating in an air or oil filled cylinder. Time adjust-



AB — OPERATING SECTION OF COIL
BC — RETARDING SECTION OF COIL
D — DASH POT

FIG. 7. ACCELERATOR WITH DASH POT AND CURRENT RETARDATION COIL.

ments are provided by needle valves or adjustable openings which regulate the oil or air pressure on the piston as it moves in the cylinder. Release valves are also provided in the piston so that it will operate freely in one direction and against pressure in the other direction.

Time Limit Starters and Controllers

In small starters and controllers the accelerating contactors are shunt contactors having the movable arms mechanically connected to the pistons of dashpots to retard their closing. In larger controllers the accelerating contactors are straight shunt contactors operated from an accelerating relay which is provided with a dashpot.

One form of controller consists of line contactors, one multi-point accelerating contactor and separate contactors for cutting out the accelerating resistance. The accelerating contactor is provided with a dashpot, operating coil and a current retardation coil. This contactor governs the closing of the separate accelerating contactors. Fig. 7 illustrates the current retardation principle used in connection with the dashpot on this contactor. The operating coil which is across the line is opposed by the action of the retardation coil which is energized by th evoltage drop across a section of the starting resistor. This type of control is built by the Rowan Controller Co. The Clark Controller Co. also employ a dashpot for timing the accelerating steps.

Controllers in which the timing of the accelerators is produced magnetically include the Cutler-Hammer inductive time limit control, the General Electric magnetic time limit control and the Westinghouse magnetic time limit control.

Cutler-Hammer Inductive Time Limit Control

In the inductive time limit controller the timing is produced through the medium of a transformer. The accelerating contactors are equipped with shunt

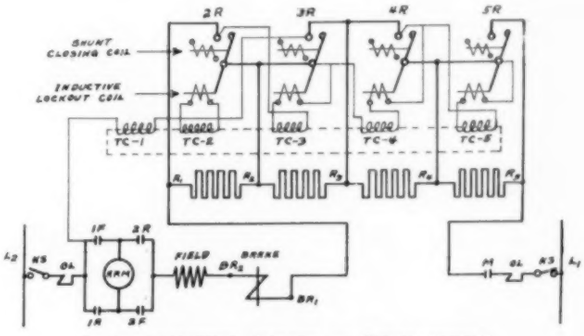


FIG. 8. ELEMENTARY DIAGRAM OF CUTLER-HAMMER INDUCTIVE TIME LIMIT CONTROL

closing coils and shunt lockout coils. The shunt closing coils are excited by line voltage while the lockout coils are excited from a transformer. The transformer consists of a heavy iron core on which are mounted one primary coil and a secondary coil for the plugging contactor and each accelerating contactor. Fig. 8 illustrates the connections of the various transformer coils and shunt lockout coils.

In starting from rest a very low voltage is impressed on transformer coil No. 1 (TC-1) and it has little or no effect. Transformer coil No. 2 (TC-2) is merely short circuited on the lockout coil of the first accelerator 2R. However, when the power circuit is completed a voltage drop is impressed on each of the remaining lockout coils which are in series with their corresponding transformer coils. The excitation due to this voltage drop which prevents the contactors from all closing at once. Due to the flux set up in the iron core of the transformer by the transformer coils No. 3 and No. 5 bucking No. 4 a current is induced in TC-2, which holds out the first accelerator (2R). The holding out period is determined largely by the design of

the control but there is an adjustable air gap in the magnetic circuit of the contactor which provides time adjustment. When the first accelerator (2R) closes transformer coil No. 3 is short circuited causing a change in flux in the transformer core. This change in flux sets up a current in the short circuited coil TC-3, which controls the holding out period of the second accelerator (3R) in the same manner as for the first accelerator. When 3R closes transformer coil No. 4 is short circuited in the same manner as the preceding coil and the same action takes place again controlling the closing of 4R. This action is repeated for each accelerator until all the resistance has been shorted out and the motor is across the line.

General Electric Magnetic Time Limit Control

The magnetic time limit control of the General Electric Co. employs shunt relays which govern the time of closing of the accelerating contactors. These relays are designed to have a definite time lag due to self induction of a short circuited coil. The relays consist primarily of a shunt coil in a magnetic circuit with a movable armature provided with a tension spring and numerous non-magnetic shims for varying the air gap between the core and the armature.

Fig. 9 illustrates the connections of the various relay coils on a simple reversing control panel. PF and PR are the plugging relay coils and 1A and 2A

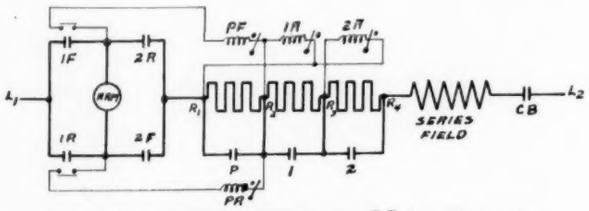


FIG. 9. ELEMENTARY DIAGRAM OF G.E.CO. MAGNETIC TIME LIMIT CONTROL

are the accelerating relay coils. The accelerating relays are the same as the plugging relays except that they have normally closed contacts. The plugging relays are connected across the armature and the first step of the plugging resistor with a mechanically operated contact in the coil circuit, operated by the proper directional contactor. The accelerating relay coils are connected across steps of the starting resistor.

In starting from rest the voltage drop through the resistor sections is impressed on the relay coils and all pick up. The plugging relay which is normally open, closes and completes the circuit for the operating coil of the plugging contactor and it closes immediately. The accelerating relays, which have normally closed contacts, open, breaking the circuit for the operating coils of the accelerating contactors. When the plugging contactor closes the operating coil of the first accelerating relay is short circuited and will close after a definite time required for the decay of the flux holding the armature open. This time can be varied by changing the spring tension or varying the air gap between the core and the armature. When this relay closes it completes the circuit for the opearting coil of the first accelerating contactor and it closes immediately. In closing, the first accelerator short circuits the operating coil of the second accelerating relay and the action is the same as before. This continues until all resistance steps are cut out.

In plugging, the counter voltage of the motor opposes the voltage drop in the plugging resistor resulting in little or no voltage on the plugging relay coil. As the motor comes to a stop the counter voltage decreases and the voltage drop becomes effective in exciting the relay coil. This closes the plugging contactor and the acceleration is the same as before.

Westinghouse Magnetic Time Limit Control

The Westinghouse time limit control employs a special plugging relay and definite time accelerating relays to govern the time of closing of the plugging and accelerating contactors. The plugging relay which governs the operation of the first accelerating or plugging contactor consists of a fixed and a movable coil and their magnetic circuits. The fixed coil is permanently connected across the line and furnishes a unidirectional field in which the movable coil acts. The movable coil is connected across the armature. Hence, for one direction of rotation the movable coil is repelled while for opposite rotation it is attracted. During plugging the movable coil retains its original polarity until the armature rotation has almost ceased. Then the polarity is reversed and the relay contacts close energizing the plugging contactor. The definite time accelerating relay consists of a shunt coil in a magnetic circuit

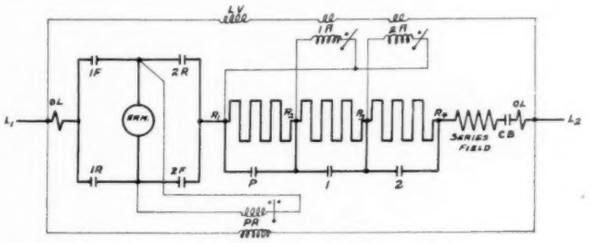


FIG. 10. PRINCIPLES OF WESTINGHOUSE TIME LIMIT CONTROL

having a movable armature provided with a tension spring for various time adjustments. The relay is designed to have a definite time lag due to self induction when the operating coil is short circuited. The relay coil is made up of two sections, one of comparatively few turns called the neutralizing coil and one of a large number of turns called the main coil. The neutralizing coil is energized at all times and opposes the magnetizing effect of the main coil thereby bucking the residual magnetism down to zero. This allows arm to arm contact, with greater time delay, yet prevents residual magnetism holding the armature indefinitely.

Fig. 10 shows the connections of the relays as applied to a reversing control panel. PR is the plugging relay which governs the operation of plugging contactor P and 1A and 2A are the accelerating relays which govern the closing of the accelerating contactors 1 and 2.

In starting from rest the voltage drop across the resistor sections is impressed on the main coils of the accelerating relays and they all pick up opening their contacts. The movable coil of the plugging relay is energized by the voltage drop across the armature and it picks up allowing the plugging contactor to close. When the plugging contactor closes the main coil of the first accelerating relay is short circuited and it closes after a definite time

required for the decay of flux. This time can be varied by varying the tension of the adjusting spring on the relay armature. When the relay contacts close they complete the circuit for the operating coil of the first accelerating contactor and it closes immediately. In closing the first accelerating contactor short circuits the main coil of the second accelerating relay and the action is the same as before. This continues until all of the accelerating contactors are closed.

Rules Governing the Operation of High Tension System

(Continued from page 202)

leased. He shall then complete and sign them and send the originals to the Superintendent of Electrical Department, and one copy of each to the General Foreman in whose section the station is located, and place one copy of each on the station file to be held for at least one month.

(k) When power is cut off, sub-station attendant must immediately trip all breakers on sub-station side of bus.

7. When work other than changing fuses, charging lightning arresters, and operating disconnecting switches is to be done on or near high tension circuits or apparatus, the man in charge of the work must proceed as follows:

(a) In case work is to be done on circuit or apparatus on the station side of disconnecting switches that disconnect station from incoming circuit, or on outgoing circuits from sub-stations, he shall apply to the attendant for a permit to do the work, stating its nature, the point at which it is to be done, its probable duration, and naming the circuit or apparatus that must be cut to permit of work being done. The attendant will verify the request by reading it aloud to the person making it, after entering it on High Tension Order Form No. ..... The man in charge of the work must insist on receiving this verification.

(b) He shall then await notification from the attendant that the circuit or apparatus has been deadened. After receiving this notification, he shall, if practicable, see for himself that disconnecting switches have been opened, and that a ground and short circuit has been applied between the point at which the work is to be done and each station or stations connected. He may then proceed with his work.

(c) When work is to be done in the proximity of high tension circuit or apparatus that cannot be deadened while the work is being done, the man in charge of the work shall satisfy himself that the men who are to do the work thoroughly understand the exact location of the live equipment and shall plan with them a working method that will enable them to do the work safely.

(d) It shall not be permissible to attach any rigging on any high tension electrical conductor for the purpose of supporting or hoisting any material whatsoever.

(e) Each man in charge of a gang that desires to work on a circuit or apparatus must obtain a permit and satisfy himself that grounding and short circuiting devices have been applied, even though other gangs are at work on, and have protected, the circuit or apparatus.

8. When repairmen from Electrical Shop go to the Motor Houses, Pump House, or sub-station to make repairs on motor-generators, rotaries, or other equipment, they shall, before starting work, report to the General Foreman or attendant whose duty it shall be to see that all necessary precautions are taken to protect the repairman.

NATIONAL WELDING CONFERENCE

(Continued from page 111)

Mr. A. M. Candy, Westinghouse Electric and Manufacturing Company, pointed out the advantages of arc welding over rivets in crane assembly and building.

Mr. S. L. Henderson, Electrical Superintendent, American Steel & Wire Company, pointed out the advantages of arc welding in maintenance departments.

Mr. Grover Hughes, Electrical Engineer, Truscon Steel Company, Youngstown, Ohio, discussed the first portable 100 per cent electric welded building —built by his company in 1915 for the Russian Government.

Mr. E. H. Martindale, President, Martindale Electric Company, brought up the relative merits of D.C. and A.C. Welding.

Mr. John Lincoln answered this question claiming that those who had experience with both types would grant that D.C. machines produced on the average better welds. Mr. Grover Hughes presented a discussion covering the relative merits of D.C. and A.C. Welding.

STATEMENT OF OWNERSHIP, MANAGEMENT, ETC., OF

IRON AND STEEL ENGINEER

(Required by Act of Congress of August 24, 1912)

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Editor—John F. Kelly, Empire Bldg., Pittsburgh, Pa.

Business Manager—John F. Kelly, Empire Bldg., Pittsburgh, Pa.

Names and addresses of stockholders holding 1 per cent or more of total amount of stock: None.

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Known bondholders, mortgagees and other security holders owning or holding 1 per cent or more of total amount of bonds, mortgages or other securities: None.

JOHN R. DOYLE, Asst. Editor.

Sworn to and subscribed before me this 19th day of March, 1928.

LEAH H. RUGG, Notary Public.

(My commission expires January 20th, 1930.)

LIST OF EXHIBITORS

Iron and Steel Exposition

Hotel Stevens **Chicago, Illinois**

June 25, 26, 27, 28, 1928

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Aluminum Co. of America
Appleton Electric Co.

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Bartlett Hayward Co.
Benjamin Electric Mfg. Co.
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